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HOW TO FORECAST Truck Fuel

DATA developed from a joint industry-Government field test program, over two stretches of highway in Pennsylvania, make it possible to predict the gasoline consumption and travel time of trucks. This applies to vehicles operating over paved highways in any part of the country that do not exceed an average altitude of 3000 ft.

This year and one-half study, involving seven

Truck Economics Nomenclature

1. Total rise and fall: Arithmetic sum of the vertical rise and fall in feet for any section of highway. For example, if a highway section progressively rises 100 ft, falls 500 ft, rises 30 ft, and falls 10 ft, total rise and fall will be 640 ft. Total rise and fall is the same regardless of direction of travel.

2. Rate of rise and fall: Total rise and fall for any section of highway divided by the length of section in hundreds of feet. If the total rise and fall is 640 ft and the length of section is 20,000 ft, then the rate of rise and fall is 3.2 ft per 100 ft.

3. Gross horsepower: The brake horsepower of the engine—operating without accessories, such as fan, air compressor, generator, muffler, and so forth—that is available at the clutch or its equivalent.

4. Net horsepower: The brake horsepower of the engine—operating with all its normal accessories—that is available at the clutch or its equivalent.

5. Weight-power ratio: The ratio of gross weight of the vehicle or combination of vehicles to the gross or net horsepower of the powered unit. In this study, the weight-power ratio is determined by using the net horsepower.

6. Gasoline consumption: The gallons of gasoline consumed per mile of highway travel. Conversion from gallons per mile to miles per gallon is easy since one is a reciprocal of the other.

7. Travel time: The minutes required to travel one mile of highway.

8. Composite gasoline consumption: The total number of gallons of gasoline required by a vehicle of a given weight to travel in both directions on a section of highway, divided by twice the length of the section in miles.

9. Composite travel time: The sum of the minutes required by a vehicle of a given weight-power ratio to travel in each direction on a section of highway, divided by twice the length of the section in miles.

10. Directional gasoline consumption: The gallons of gasoline consumed by a vehicle in traveling in a single direction over a section of highway, divided by the length of the section in miles.

11. Directional travel time: The minutes required for a vehicle to travel in a single direction over a section of highway, divided by the length of the section in miles.

Consumption and Travel Time

EXCERPTS FROM PAPER* BY

Carl Saal, Highway Transport Research Branch, Bureau of Public Roads

* Paper "The Gasoline Consumption and Travel Time of Motor Trucks," was presented at SAE Summer Meeting, French Lick, Ind., June 9, 1950. This paper will be printed in full in SAE Quarterly Transactions.

trucks, pointed up three significant relationships. First, both gasoline consumption and travel time vary in a definite manner with the rate of rise and fall. (See nomenclature on p. 18 for definition of rate of rise and fall and other terms.) This relationship is not affected by the length of section, or number and steepness of individual grades in the section. Second, gasoline consumption is related to gross weight. And third, travel time is related to the weight-power ratio.

Analysis of the basic test data produced the composite consumption shown in Fig. 1. Gasoline consumption in Fig. 1 is related to the rate of rise and fall for 14 gross weights, ranging from 10,000 to 140,000 lb.

The family of curves in Fig. 1 is the final answer to composite gasoline consumption. If the total rise and fall in a highway section and the gross weight are known, it is very simple to determine the gasoline consumption.

Weight, Power Affect Time

Composite travel time was analyzed in the same way as composite gasoline consumption. Only difference is that travel time is related to pounds of gross weight per net horsepower. Composite travel time related to rate of rise and fall for pounds per net horsepower, ranging from 100 to 600 by increments of 50, is shown in Fig. 2. Just as Fig. 1 is the final answer to composite gasoline consumption, Fig. 2 is the story in a nutshell on travel time.

Both of these charts are required to solve problems on composite gasoline consumption and travel time.

Note that in Fig. 2 the curves converge to a travel time of about 1.2 min per mile for a zero rate of rise and fall. This is equivalent to an average speed of 50 mph on the level for any weight-power ratio. It compares closely with average spot speeds observed for test vehicles on level sections. This means that other factors, such as speed limtis and traffic conditions are the limiting factor in top speed rather than the available engine power.

The composite relations shown in Figs. 1 and 2 will help solve many problems which confront the transportation economist. But their use is limited. They are restricted to problems where commercial vehicles have about the same weight or weight-power in each direction of travel over a highway section. Considering an individual vehicle, they can be used only where the same weight is hauled

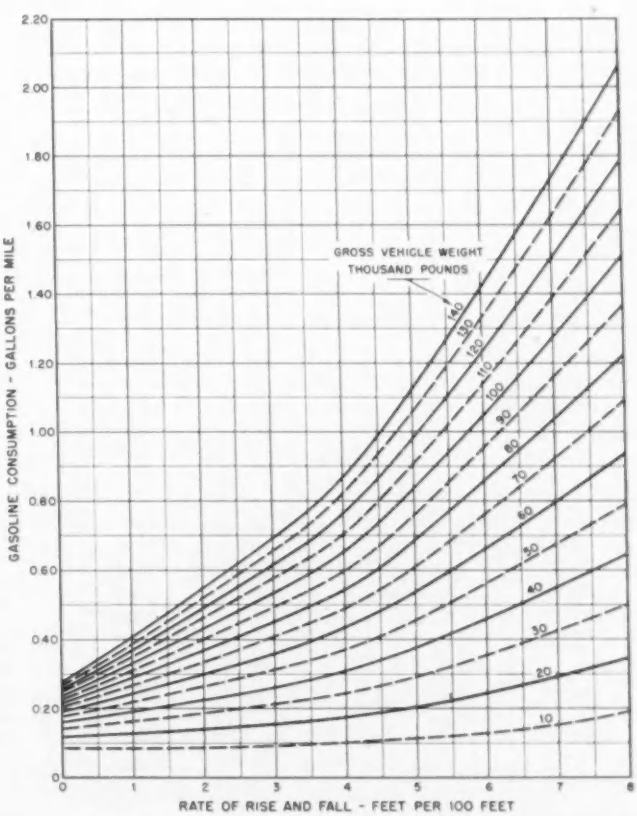

Fig. 1—Composite gasoline consumption for various gross weights related to the rate of rise and fall

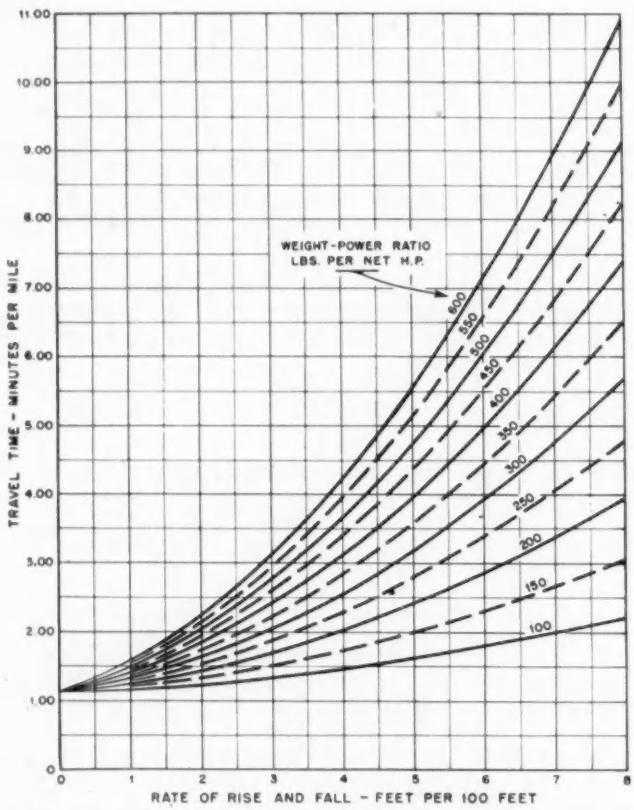

Fig. 2—Composite travel time for various weight-power ratios related to the rate of rise and fall

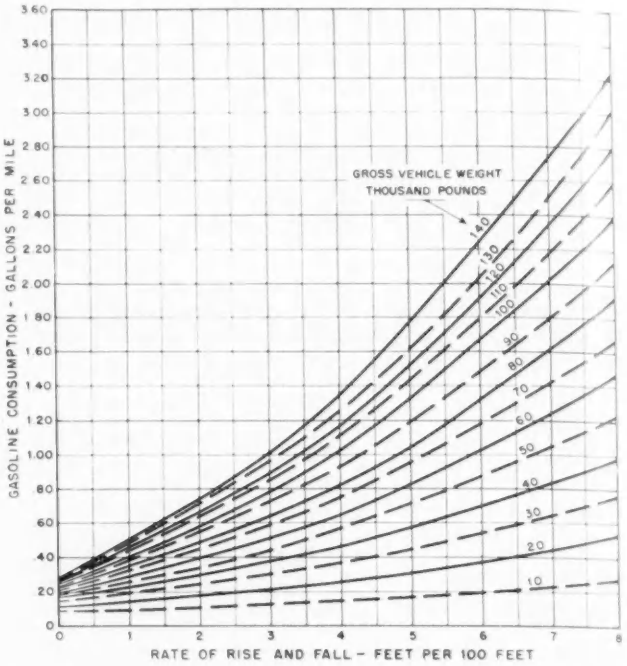

Fig. 3—Directional gasoline consumption for various vehicle weights related to the rate of rise and fall when the rise is 75 to 84% of the total rise and fall

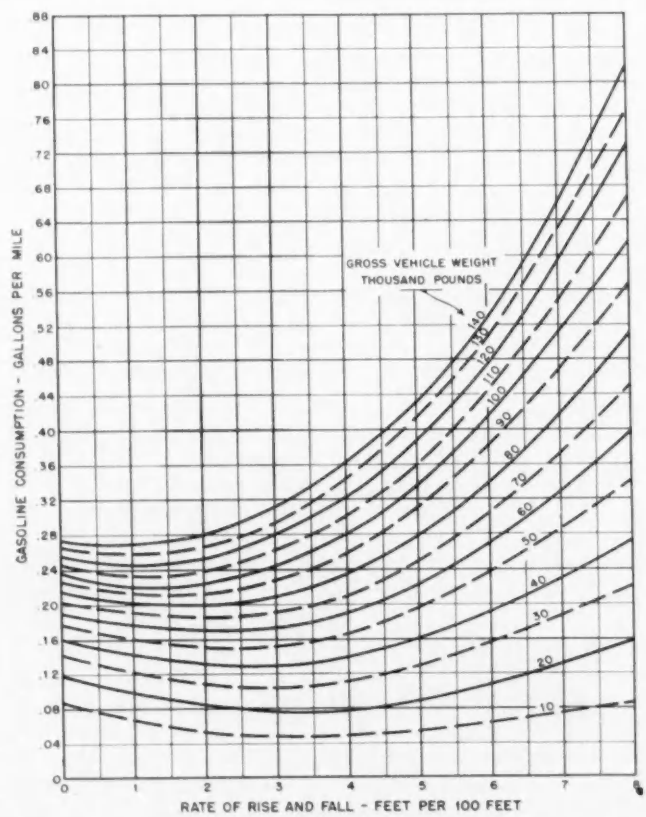

Fig. 4—Directional gasoline consumption for various gross vehicle weights related to the rate of rise and fall when the rise is 15 to 24% of the total rise and fall

in each direction of travel over a highway section.

This is not always the case. For example, on access roads to heavy industry or mining operations, vehicles are often loaded much heavier in one direction than the other. And when considering any given vehicle, it may be loaded in one direction and empty in the other; or it may use different routes in going and returning. When such conditions exist, the composite gasoline consumption and travel time cannot be used.

It is important to remember that composite values are the average rates of gasoline consumption or travel time for a round trip over a section with a given gross vehicle weight or weight power ratio. The composite value cannot be applied for travel in one direction over a section unless the total rise approximates the total fall.

One-Way Data

Development of gasoline consumption and travel time on a directional basis introduced an additional factor—the rise in the direction of travel as a percentage of total rise and fall. A family of curves similar to those in Figs. 1 and 2 were developed for each of 10 percentage groups. They range from the condition when the rise in the direction of travel is 95 to 100% of total rise and fall to that when the rise in the direction of travel is 0 to 4% of the total rise and fall.

The intermediate percentage groups are 85 to 94, 75 to 84, 65 to 74, 55 to 64, 35 to 44, 25 to 34, 15 to 24, and 5 to 14. When the rise in the direction of travel is 45 to 54% of total rise and fall (the rise about equals the fall), the composite values in Figs. 1 and 2 are to be used.

Directional gasoline consumption for various gross weights is shown in Fig. 3 for a rise in the di-

re ion of travel of 75 to 84% of total rise and fall, an in Fig. 4 for a rise of 15 to 24%. The two charts sh w the typical relationship between directional co sumption, rate of rise and fall, gross weight, and th rise in percentage of total rise and fall.

he relationship between the directional travel ti e, the rate of rise and fall, and the weight-power ra io is shown for the same percentage groups in Fi s. 5 and 6.

The results in Figs. 1 to 6 can be used to estimate the average gasoline consumption and time required to operate a particular vehicle or groups of vehicles on a given section of highway.

Table 1 is a computation form that shows how results of this study can be applied to determine gasoline and time economy of any commercial vehicle for a specific highway profile. It demonstrates a method for computing factors that relate to economy of operation consdiering the composite gasoline consumption and travel time.

The step-by-step procedure is illustrated by actual calculations for an assumed vehicle. Remember that only two segments of the total operating economy can be evaluated by the use of this computation form. Overall cost comparisons cannot be made until other important factors, such as cost of tires, maintenance, depreciation, and overhead are determined.

Preliminary Trends

"How does the operating economy of commercial vehicles vary with gross vehicle or combination weights?" is the $64 question. It cannot be answered until other segments of operating costs are determined by a research project now being organized. If the answer should be better operating economy with increasing weight, economy of operating various numbers, types, and weights of vehicles still must be related to cost of providing highway facilities for these vehicles.

This study has not provided all the factors required. But it has furnished a means for determining the trend in operating economy as regards gasoline consumption and travel time.

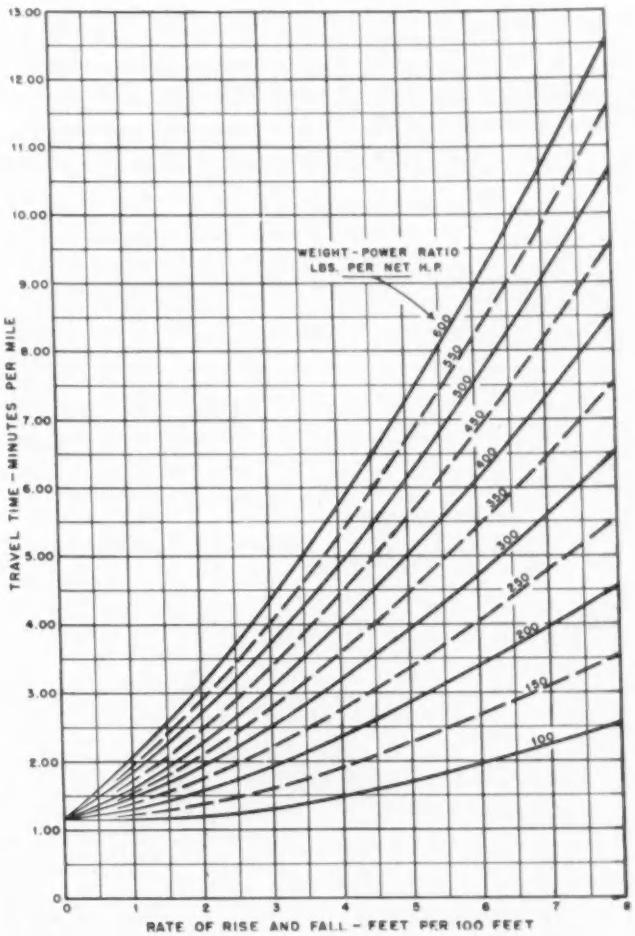

Fig. 5—Directional travel time for various weight-power ratios related to the rate of rise and fall when the rise is 75 to 84% of total rise and fall

Using the method demonstrated in Table 1, oper-

Table 1—Computation Form for Determining Ton-Miles per Gallon and Ton-Miles per Hour for Any Commercial Vehicle

Item No.	Items and units	Value	Remarks
1	Total rise and fall of highway, feet	375	Obtained from profile map or by altimeter
2a	Length of highway, feet	30,000	Obtained from profile map or odometer
b	, hundreds of feet	300	Item 2a divided by 100
3	Rate of rise and fall, ft/100 ft	1.25	Item 1 divided by item 2b
4	Type of vehicle or combination	.....	Type being studied
5	Net engine horsepower	180	From manufacturer's specifications
6	Empty (tare) weight, pounds	30,000	From scale
7a	Gross vehicle or combination weight, pounds	72,000	From scale or estimated
b	, tons	36	Item 7a divided by 2,000
8a	Payload (net) weight, pounds	42,000	Item 7a minus item 6
b	, tons	21	Item 8a divided by 2,000
9	Weight-power ratio, lb/net hp	400	Item 7a divided by item 5
10a	Gasoline consumption, gal/mile	0.29	From Fig. 1 for items 3 and 7a
b	, mile/gal	3.45	One (1) divided by item 10a
11a	Travel time, minutes/mile	1.50	From Fig. 2 for items 3 and 9
b	, miles/hour	40	60 divided by item 11a
12a	Gross ton-miles per gallon	124	Item 10b times item 7b
b	Payload ton-miles per gallon	72	Item 10b times item 8b
13a	Gross ton-miles per hour	1,440	Item 11b times item 7b
b	Payload ton-miles per hour	840	Item 11b times item 8b

ating economy in terms of gross ton-miles per gallon and gross ton-miles per hour has been computed for various gross weights, ranging from 10,000 to 140,000 lb, and for rates of rise and fall ranging from 0 to 8 ft per 100 ft.

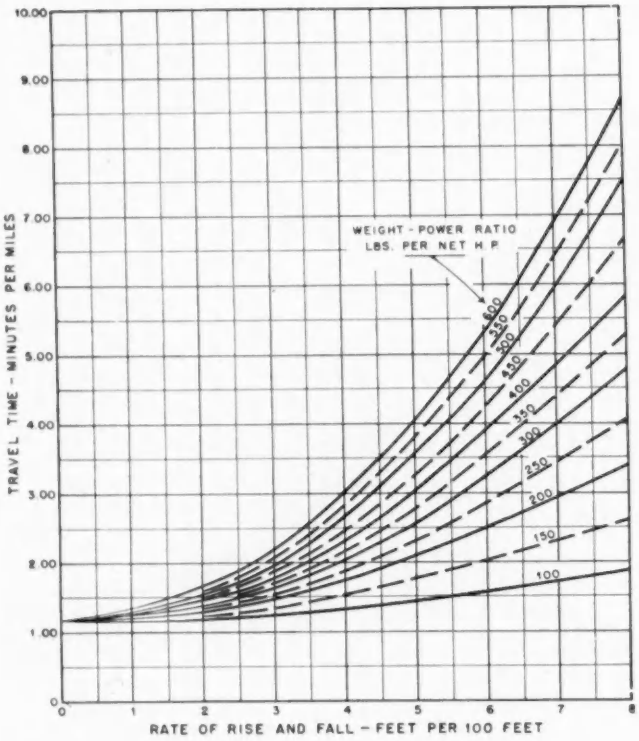

Fig. 6—Directional travel time for various weight-power ratios related to the rate of rise and fall when the rise is 15 to 24% of the total rise and fall

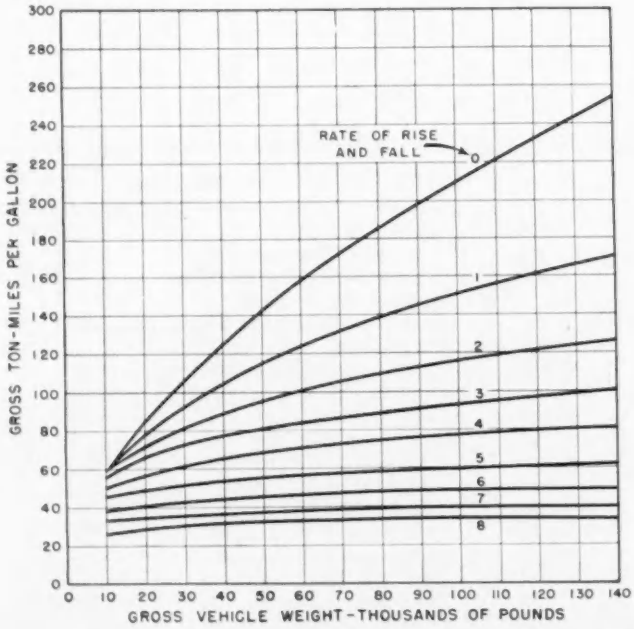

Fig. 7—Variation of gross ton-miles per gallon with gross vehicle weight for various rates of rise and fall

Relation between gross ton-miles per gallon and gross weight is shown in Fig. 7 for various rates of rise and fall. Gasoline economy on the basis of gross weight does increase appreciably for the lower rates of rise and fall. For rise and fall rates greater than 2, operational economy does not increase substantially for the heavier weights. Incidentally, many of our highway sections have rise and fall rates greater than 2.

Weight Saves Time

Fig. 8 shows the variation of gross ton-miles per hour with gross weight and the rise and fall rate for a weight-power ratio of 400. Similar results can be developed for other weight-power ratios. But the direction of the trend would be the same. Operating economy—considering time—increases with weight, regardless of the rate of rise and fall. The slope of the lines indicates this. The time economy does not tend to level off at the higher gross weights, as was the case for gasoline economy.

Figs. 7 and 8 show that operating economy (considering only gasoline consumption and time) does increase with weight, at least for the lower rise and fall rates. Overall operating economy may or may not follow the preliminary trends based on the gross weight and the two elements of the operating cost. Payload tons as well as gross tons must be considered in a comprehensive analysis of operating economy.

The paper on which this article is based is available from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

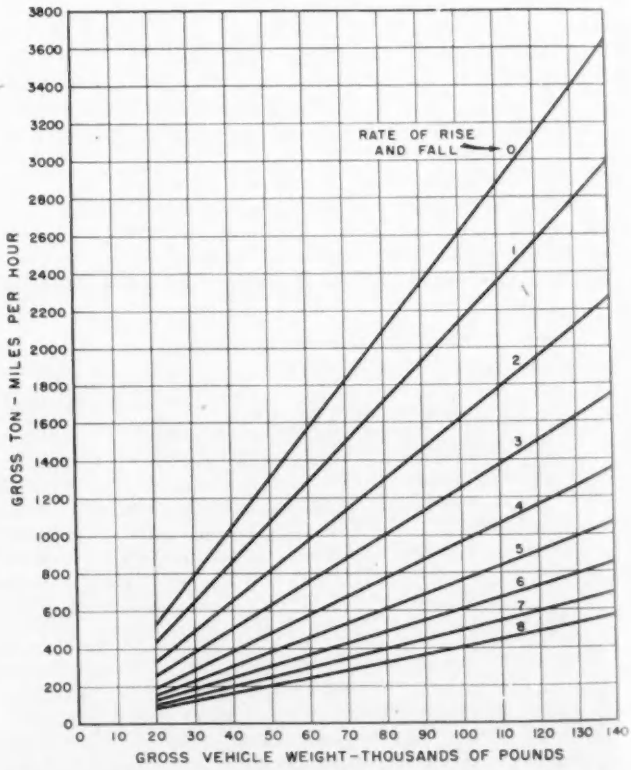

Fig. 8—Variation of gross ton-miles per hour with gross vehicle weight for a weight-power ratio of 400

Automatic Transmissions ....Today's and Tomorrow's

EXCERPTS FROM PAPER* BY

A. H. Deimel, Chief Engineer, Hydraulic Transmission Division, Spicer Mfg. Division of Dana Corp.

* Paper "Automatic Transmissions—Today—Tomorrow," was presented at SAE Summer Meeting, French Lick, Ind., June 6, 1950.

THE five passenger car automatic transmissions which have appeared since the War—Buick's Dynaflow, Packard's Ultramatic, Chevrolet's Power-Glide, the Studebaker, and the Ford-Mercury—are similar in certain features and different in others. This is to be expected since there are many factors to be considered, and various features will be given different weight and importance by different designers.

Considering first the points of similarity:

1. Hydraulic torque converters are included in the drive.
2. Rotating housing high speed converters are used.
3. Reaction blading is carried on a freewheel.
4. Planetary low and reverse gears are used behind the converter.
5. These gears are applied by oil pressure operated clutches.
6. Two auxiliary pumps are used to create oil pressure for the clutches and to keep the converter under pressure.
7. Five position control levers are provided for Parking, Neutral, Drive, Low and Reverse.
8. Positive lock of drive shaft provided by Parking position.
9. Engine starting possible only in Park or Neutral positions.

While there are many differences in construction and materials, the points of immediate interest here are the differences to be noted in the methods of solving the major problems, which start with the difference in design of the hydraulic torque converters. To bring out these differences, we must first consider some facts involved in connection with converter performance.

The input or engine speed is determined by the converter blading design. If the converter has a type of blading which holds the engine speed constant over the range, then the range of output speed possible is limited to a percentage of this input speed.

For example, with an engine speed held constant at 2000 rpm and with a converter having a coupling point of 0.9, which means that the torque multiplication reaches unity at a speed ratio of 0.9, then the output speed range will extend from zero to 0.9 × 2000, or 1800. Thus, not only is the range of vehicle speed over which torque multiplication occurs limited, but the engine speed at stall is objectionably high, giving rise to noise, and causing a delay at start while engine accelerates. A study of Fig. 1 will bring out this point. If the engine speed remains constant, the speed ratio rapidly changes.

The aim of the early converter designers was to produce performance of this type, which is still useful with engines having a low governed speed. It requires operation under fairly limited speed conditions, as used in some industrial applications.

Once the value of using the engine speed range as well was appreciated, considerable work was done to develop a converter in which the input torque would decrease with increase in speed ratio. For example, assume the stall speed could be held down to 1500 and input torque required be gradually reduced so that at the same 0.9 coupling point as in the previous example, the engine speed be allowed to rise to 3000. Then the output speed at that point

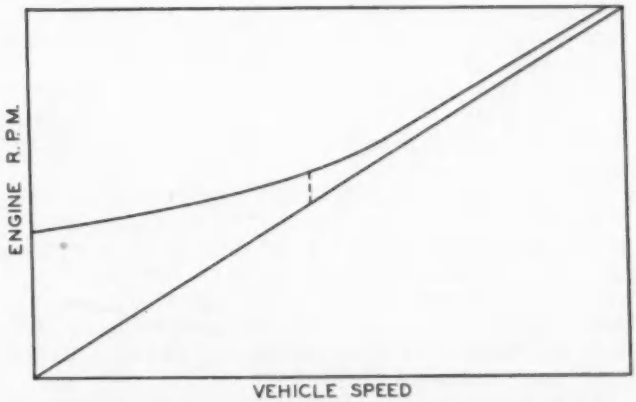

Fig. 1—Engine rpm versus vehicle speed with a torque converter transmission. Upper curve is engine and input speed. The lower straight line represents the output speed. Difference between the two lines determines the speed ratio. If the reaction member is cut loose, engine speed continues up as with a coupling. Now the difference between the two lines is slip

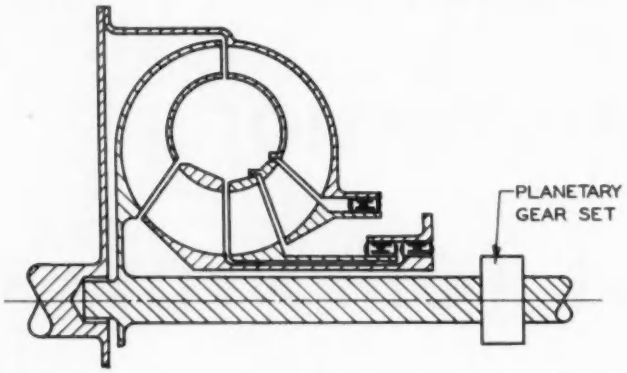

Fig. 2—The single-stage, five member torque converter is used in both the Buick Dynaflow and Chevrolet PowerGlide automatic transmissions

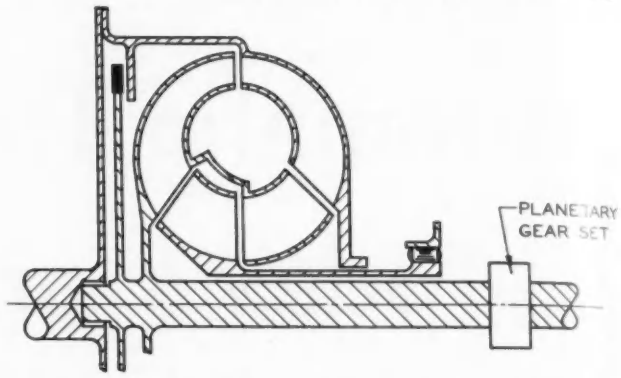

Fig. 3—Packard's Ultramatic transmission uses a two-stage, four member converter. At higher speeds a friction clutch, black member at left, locks together turbine and pump so that the unit operates as a direct drive

would be 0.9 × 3000 or 2700. This gives a far wider range, even though the stall speed at the start is desirably lower.

The total speed range is produced by the combination of engine and converter. If the engine torque curve drops steeply with increase of speed then the range obtained is limited.

There are many factors which affect the input torque characteristics of a converter with change of speed ratio. As one example, the fluid flow into the converter pump is determined by the blade set preceding the converter. If this blade set is stationary, then the fluid leaves in a fixed direction which is the case when the blade set preceding the pump is a stationary reaction set.

If, however, the blade set preceding the pump is a set of turbine blading, then at stall, with the turbine stationary, the fluid can be directed to flow backwards, against the direction of rotation of the pump, holding the pump down to low speed under this condition. With increasing speed of the turbine, the fluid rotates with the turbine and acquires a speed in the forward direction. At high speed ratios this forward speed becomes considerable and cancels out the former direction of fluid flow against rotation of the pump. The fluid now rotates with the pump, reducing the driving torque required, and permitting the engine to speed up.

Thus, the three element, single-stage converter is essentially a constant input speed converter, since the pump is preceded by a stationary guide blade set.

In the Buick and Chevrolet single stage converters the desired rising speed characteristic is produced by making the pump blading in two sections. One set of blades floats on the other by means of a freewheel. Furthermore, the range of the converter is extended by splitting the guide blades into two sections, each mounted on a freewheel to the stationary carrying sleeve.

Thus at low speed ratios, the combined curvature of both sets of reaction blading produces high torque multiplication. At high speed ratios, the steeply curved section floats. The remaining guide section with limited curvature is better suited to the changed flow direction of the fluid leaving the turbine, which is now rotating at speed, and the effective range of the converter is thus extended. Beyond the coupling point, the second guide set also rotates. The converter then acts as a coupling.

By virtue of a somewhat more complex blading design, having five sets of blades instead of three, the single-stage converter is made to produce a wide enough range of operation, including use of engine flexibility and speed range, so that over the whole normal driving range no shifts are required.

At start, the maximum torque multiplication of 2.25 is produced. This torque multiplication gradually falls off as vehicle speed increases. The vehicle speed, at which all torque multiplication ceases and the unit becomes a coupling, depends on the throttle opening. The changes in phase of operation take place automatically and imperceptibly in accordance with the speed ratio.

Thus the unit may be operating at medium speed as a coupling. Opening the throttle will cause the engine to speed up, changing the speed ratio, and torque multiplication is again produced. At high vehicle speeds, the unit functions as a coupling only.

For extreme acceleration at low speeds, for steep grade climbing, and for braking resistance on steep hills, the planetary low ratio behind the converter is engaged by moving the control lever to the low position, the necessary clutch engagement being made by oil pressures. Fig. 2 shows the construction in its bare essentials diagrammatically.

In a bus converter, higher torque multiplication is required at each start due to the much lower power weight ratio. The necessary multiplication is produced by the three-stage converter, having three sets of turbine blades with two sets of guide blades interposed. The fluid leaves the last set of turbine blades to enter the pump, engine speed increasing with vehicle speed to give sufficient range of operation until direct drive is engaged.

In the Packard converter the desired engine speed range is produced by the two-stage blading design used, having four sets of blades with a turbine set preceding the pump. For high speeds, the converter becomes a coupling, and the reaction member floats on a freewheel. About the time this takes place a friction clutch locks the turbine and pump

together; the unit then functions as a direct drive with no slip.

Fig. 3 shows the essentials of this construction. It is of interest to note that the duty of the direct lock up clutch is simplified somewhat as compared to a clutch used in connection with a mechanical gear. At start of engagement the converter is transmitting the full torque, and the speed difference is small. As the clutch engages, the speed difference decreases; and due to the change in speed ratio, the torque transmitted by the converter is reduced. Thus by the time the clutch takes over the full torque, the speed difference is very small. With a shift in connection with a mechanical ratio the clutch must take over the full torque before the speed ratio can be changed at all.

The direct clutch eliminates the slip always present when the converter is used as a coupling. But it requires the addition of a governor to control the shift in or out, with modification on governor action produced by the position of the throttle, so that the shift will take place at varying vehicle speeds as required. Once direct is engaged, it requires an overrule to step back into converter and produce torque multiplication. Without direct drive, torque multiplication reappears imperceptibly, being simply dependent on the speed ratio.

In the Studebaker design, which is shown diagrammatically in Fig. 4, we find the problem handled in a still different manner. The three element, single-stage torque converter is used, which tends to permit but limited engine speed increase over its effective range while producing torque multiplication. It is combined with a planetary gear reduction behind the converter having a ratio of 1.435 to one. The torque multiplication consists of the sum of the converter multiplication and the gear multiplication.

After the converter multiplication disappears and the unit becomes a coupling, the engine then accelerates with the vehicle at constant torque multiplication of 1.435. The action then is similar to accelerating the vehicle in second gear. High gear is provided by a direct drive clutch which connects the engine direct to the output shaft. This in effect shorts out both converter and gear reduction. Here the clutch must take over the full torque before the speed ratio can be reduced below that of the gear set. The gear set must be provided with a freewheel so that it can overrun with the unit locked up in direct; otherwise, the converter would have to churn at high loss.

While the duty of the direct clutch here is therefore greater than if used to lock up converter alone, it is still simpler than two friction clutches used to shift a mechanical ratio, since the second clutch in this case is a freewheel.

This direct clutch again requires a governor whose action is modified by the amount of throttle opening, so that the shift to direct drive will take place at various vehicle speeds in accordance with the acceleration desired. Thus the unit can be made to provide high acceleration ratio up to high vehicle speed. An overrule is provided which is brought into action by extra pressure on the accelerator.

The Ford-Mercury design again provides a somewhat different solution. No direct drive clutch is provided. The hydraulic unit remains in the drive circuit at all times. It functions as a torque converter at low speeds and becomes a coupling at high speeds, the reaction member then floating on a freewheel. The converter consists of a three-member, single stage system, as shown in Fig. 5.

Like the Studebaker, which also uses a simple three-member, single-stage converter, three ratios are provided behind the converter—low, intermediate, and high. The shifting into low again is hand controlled. Shifting between intermediate and high is regulated by a governor with action modified by a throttle opening. Instead of two separate planetary gear sets, which are used singly or together to provide the gear reductions, a double pinion type of gear set provides either of the two ratios by means of suitable clutches.

Thus the designers placed high value on the smoothness inherent in maintaining hydraulic drive at all times. They accept some possible sacrifice in economy due to slip to obtain this smoothness. On the other hand, they chose the simplest design of a hydraulic three-member unit, which required the complication of a governor-controlled automatic gear shift with over-rule to meet the performance required.

On closing the throttle on the transmissions which have a direct drive, the engine supplies braking resistance exactly as on a conventional car. The axle drives the engine by means of the direct drive clutch. On those not having the direct drive, the converter

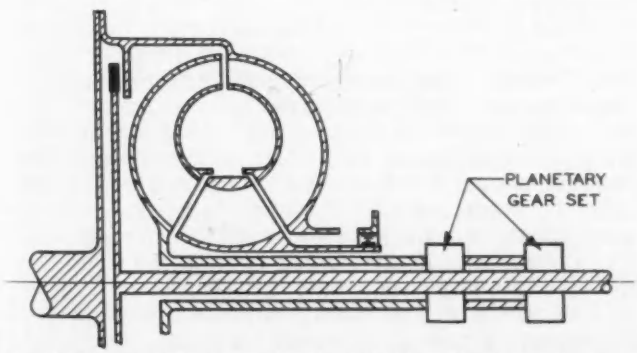

Fig. 4—The Studebaker automatic transmission combines a single-stage, three element converter with two planetary gear sets. A direct drive clutch shorts out both converter and gear reduction

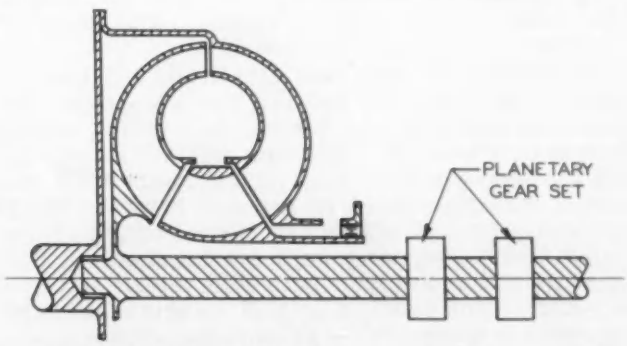

Fig. 5—Like Studebaker, the Ford-Mercury automatic transmission incorporates a single-stage, three-element converter. But unlike Studebaker, it does not have a direct lock up

becomes a coupling with the turbine driving the engine. This same action occurs in low range, the braking torque then being increased by the low range multiplication.

On the Chevrolet there is an interesting method of increasing the braking resistance. Blades are added in the center chamber of the converter vortex, which form an independent coupling. These blades are fastened to the pump and turbine. They are so formed and located with respect to each other that there is very little effect on the drive in the forward direction. But under coast conditions, they are effective in increasing the braking torque transmitted.

On the Studebaker the braking torque produced in low gear is high, due to the high multiplication of the two gear ratios used behind the converter. The higher starting torque produced, since converter torque is multiplied by one gear ratio in the driving and two ratios on the low range, might be expected to be accompanied by more idling drag or creep. But this objection is eliminated by use of an anti-creep arrangement.

Thus in examining the various designs, we find that simplification in one part is compensated for by complication in another. The actual construction chosen is influenced by the relative weight placed on various requirements.

For example, we have the Hydra-Matic where the torque multiplication is provided entirely by gearing in four separate steps, requiring clutches and a complex automatic control mechanism. At the other end of the scale, we have the Buick and Chevrolet with the torque multiplication for the driving range produced entirely hydraulically without requiring any automatic shifting and governor controls. But the cost for this is a somewhat more complex blading system. The remaining drives come somewhere between these two extremes.

The Buick and Packard hydraulic sections are made of aluminum castings by extremely accurate casting methods, permitting the blades or vanes to be made of varying thickness. Chevrolet and Studebaker use sheet steel blading accurately formed and held in steel housings by brazing.

Ford-Mercury uses a die-cast aluminum cover with sheet steel blading. The blades have tabs which are inserted into slots. Tabs on the torus ring side are rolled over to complete the assembly. The turbine similarly is made of sheet steel blading, with tabs extending through slots in steel stampings. The tabs are bent over by rolling. The reaction member is an aluminum die casting.

To operate the clutches and bands required to control the planetary gearing two oil pumps are provided, one driven by the engine and one driven by the output shaft. Pressure regulating controls are provided which produce high pressure when required for engagement of low and reverse. They reduce the pressure at high speeds to prevent excess power loss. The two pumps are required so that pressure will be available both with vehicle stationary and engine running, or with engine stationary and vehicle being pushed to start the engine.

Coolers are provided on the converters to take care of any excess heat which may be produced. The fluid passes through the cooler, giving up its heat to the engine cooling water. On the Studebaker and Ford-Mercury, fins are provided on outside of converter which circulate cooling air and cool the converter directly.

Having now examined the automatic transmissions of today, can we venture an estimate of what lines the automatic transmissions of the future can be expected to follow? We have seen the advantages provided by hydrokinetic drive. Smoothness of starting is continually repeated without necessity of adjustment since the smoothness is inherent.

With the converter, we also obtain a flexibility over the driving range. Speed and torque ratios adjust themselves in accordance with the power demand as indicated by the throttle opening. With engine speed thus not tied rigidly to vehicle speed, we obtain continuous smooth acceleration.

With these advantages in mind it is logical to assume that future automatic transmissions will continue the trend to hydrokinetic drive. With further research in blading, we can, of course, expect further improvement in performance. But beyond this, can we look to any improvement in principle?

We have noted that the speed ratio and torque ratio are initiated by, and dependent on, throttle opening. Thus for any reduction in acceleration we must first reduce the throttle opening. The gasoline engine produces its best economy at or near full throttle opening. This fact accounts for some of the increased fuel economy with overdrive. Before and after engaging overdrive, with the vehicle operating at the same constant speed, the same horsepower must be developed. With the overdrive, the engine is running slower, but with a greater throttle opening. Thus it produces horsepower more economically.

We now regulate our vehicle speed by throttle opening. We formerly regulated the spark advance by hand. In fact on many outboard boat engines, the speed is regulated entirely by the spark advance. Just as the spark advance is now regulated automatically, it is conceivable that eventually throttle positions and speed and torque ratio will also be regulated automatically, subject merely to the command of a speed control pedal. In this manner, engine speed would be determined by the ratio needed to meet the power requirements, operation being to a greater extent at lower engine speed and wider throttle opening, with resultant better fuel economy. Change in power requirements would be met by a change in ratio over a predetermined range before making a change in throttle opening.

Hydrostatic transmissions permit performance of this type but their high losses in sizes suitable for automotive work have prevented their application. To produce this type of performance with a torque converter, some form of external control on the flow must be made available. Attempts made so far to accomplish this purpose have not been successful, since they were accompanied by reduced efficiency which offset any gain made. It is however, a direction in which improvement in performance can be found, and is therefore worthy of effort.

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TURBOPROPS Recommended For 1955 Turbine Transports

EXCERPTS FROM PAPER* BY

R. M. Hazen Director of Engineering, Allison Division, GMC

* Paper "The Case for the Turboprop Engine" was presented at SAE National Aeronautic Meeting, New York, April 18, 1950.

THE turboprop engine can and should play an important part in such commercial turbine-powered flying as is done in 1955, it appears to Allison on the basis of technical, economic, and availability considerations.

Here are some of the reasons:

1. The turboprop will give better take-off conditions and lower cruise fuel consumptions than any other turbine-type engine. It will therefore allow the smallest airplane for a given payload and distance.

2. It will give the most economical fuel costs at least at speeds up to 500 mph and, with foreseeable propeller development, probably well beyond.

3. It has the best characteristics for off-optimum-schedule conditions, therefore the greatest flexibility for a variety of commercial uses.

4. Availability of the turboprop is greater than any of the proposed more efficient turbojets excepting, of course, current low-compression-ratio fixed-nozzle types now available, which are very wasteful of fuel.

5. Future efficiency and economy improvements resulting from additional research and development will give greater dividends on the turboprop engine than on the turbojet.

6. Available turboprop engines can be applied to existing American transports with performance and economy improvements, along with the smoothness, lower fuel cost, and easier inspection and maintenance common to all turbines.

Inasmuch as Allison has designed, developed, and built reciprocating engines of single-stage-compressor, two-stage-compressor, turbosupercharged, and compounded models; both single and twin turboprop engines, and two kinds of turbojet engines in a variety of models, we can be objective about the kind of power which airplane manufacturers or airlines may select. From the engine manufacturer's viewpoint, there are a number of turbine combinations that could be built at a given time: a medium-compression-ratio single-compressor turbojet; a high-compression-ratio twin-compressor turbojet; a medium-compression-ratio ducted fan; or a medium-compression-ratio turboprop engine.

The specific fuel consumption per pound of thrust versus airspeed at 35,000 ft altitude for these turbine powerplants is shown in Fig. 1. For comparison, current low-compression-ratio turbojets are also shown. Due to security regulations, no nu-

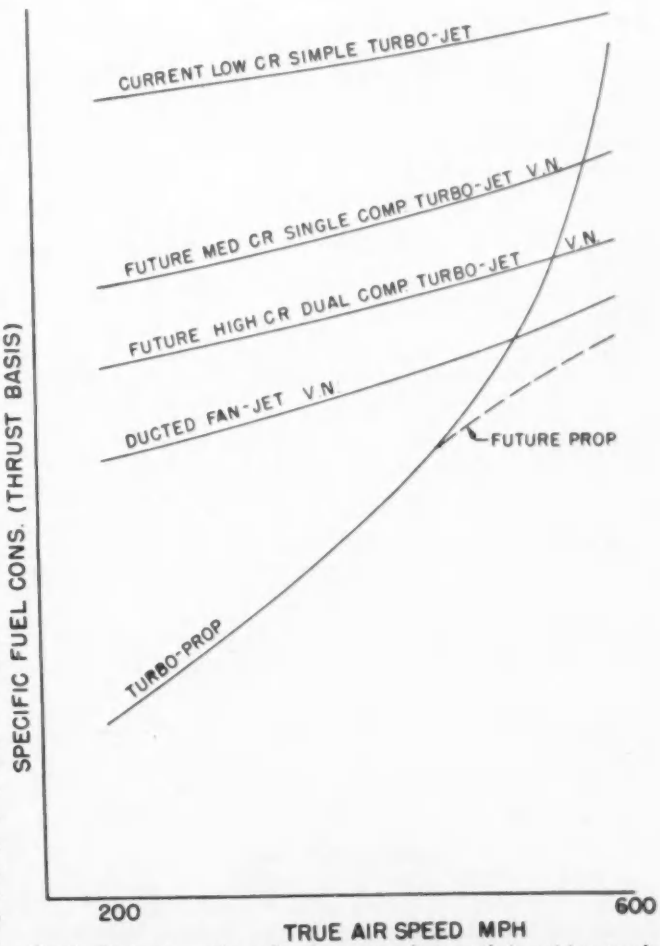


Fig. 1—Fuel consumptions of various powerplants at their cruising speeds at 35,000 ft

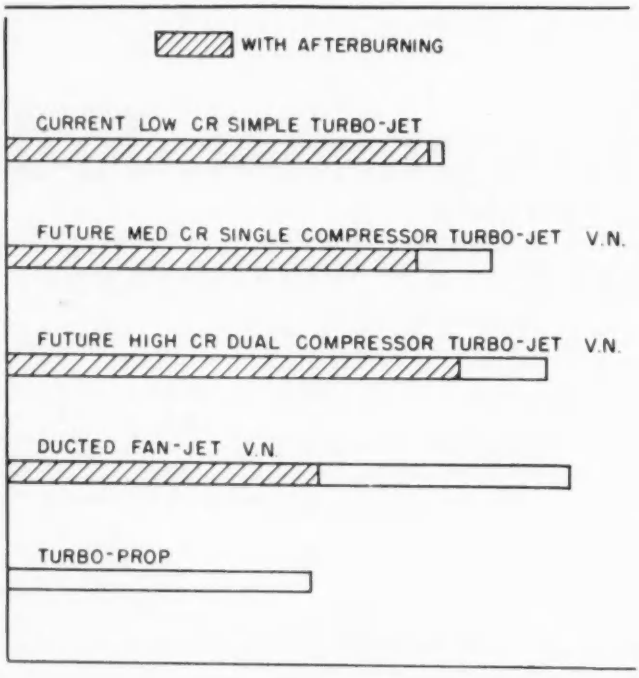
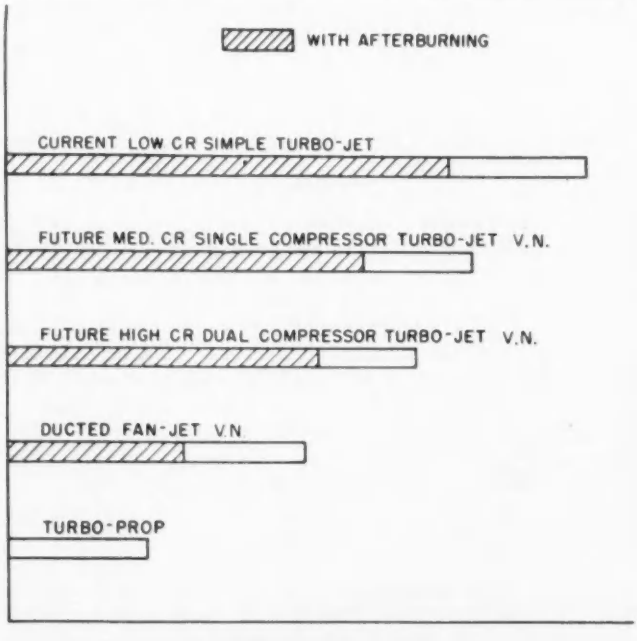


Fig. 2—Ratio of engine weight to thrust available for take-off from sea level at 70 mph for various powerplants

merical data can be given, but the curves show relative values for engines one manufacturer would produce. The solid turboprop line reflects current propeller efficiencies, and the dotted line efficiencies which appear possible with future propeller development. (For the turboprop, propeller weight is included with engine weight, and propeller efficiency is taken into account in converting power to thrust. Fuel consumption calculations for the turbojets were based on use of variable nozzles for optimum specific fuel consumption. The same take-off combustion temperature is used in all turbines except current simple turbojets.)


WITH AFTERBURNING
CURRENT LOW CR SIMPLE TURBO-JET
FUTURE MED. CR SINGLE COMPRESSOR TURBO-JET V.N.
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DUCTED FAN-JET V.N.
TURBO-PROP
ENGINE + FUEL WT
SEA LEVEL T.O. THRUST
AT 70 MPH

Fig. 3—Ratio of weight of engine plus fuel for 1000-mile range at 500 mph at 35,000 ft to thrust available for take-off from sea level at 70 mph for various powerplants

Any powerplant must take off the airplane with its powerplant load, fuel load, and payload. The powerplant governs its own weight and fuel load for a given mission and affects the basic airplane weight. Fig. 2 compares the various powerplants for the take-off condition. The bars represent pounds of powerplant weight per pound of take-off thrust at 70 mph take-off speed, an assumed average condition for a commercial airplane take-off. This is a measure of the powerplant only.

Fig. 3 shows a similar comparison for the weight of powerplant plus fuel for a 1000-mile range per pound of take-off thrust at a take-off speed of 70 mph. Since the airplane weight varies generally with the powerplant and fuel load and the payload nears a percentage figure of the airplane powerplant and fuel load, this chart represents roughly the relative gross weight of an airplane required to do a certain job.

Fig. 4 shows a similar comparison based on fuel for a 3500-mile range. To equalize the comparisons in Figs. 3 and 4 as nearly as possible, the cruising speed was taken at 500 mph. There has been at least some past agreement that 500 mph represents the dividing line between the realms of the turboprop and the turbojets.

The case for the turboprop engine for commercial airplanes for a given state of the turbine art lies largely in the above figures. The turboprop engine is outstanding in its ability to get an airplane load off the ground and in its specific fuel consumption after it gets in the air. To what maximum cruising speed this advantage will be retained depends largely on the rate of development of propellers—which depends on the funds applied to their continued development.

The usual answer of turbojet proponents to the economic advantages of the turboprop is that turbojets are so much simpler that they will be selected in any case. This statement has some merit, but it isn't fair to compare the simplicity alone of the simple single-compressor turbojet with fixed jet nozzle of our current production types with the turboprop engine with its power section, drive shaft, gearbox, propeller, and interconnecting controls. If we refer to Fig. 1, the medium-compression-ratio turboprop has a large advantage over the simple low-compression-ratio turbojet.

When we move to the medium-compression-ratio turbojet to obtain lower fuel consumptions, we find the improved fuel consumption is due more to the variable nozzle than to the higher compression ratio. Both the variable nozzle and the higher-compression-ratio compressor increase weight. This makes it all the more important that some form of augmentation be applied at take-off.

If augmentation takes the form of afterburning, the variable nozzle required is subjected to white-hot gases instead of mere red-hot gases. In either case, the correlation of power section and variable-

nozzle controls when operating parts run at high temperatures involves some sort of force-boosting provisions and reliance on temperature for the controlling means of both fuel flow and nozzle position. These controls must be extremely dependable.

Any debating done as to whether turboprop controls are more complicated than turbojet controls with variable nozzles and possibly afterburning should at least take into account the difference in temperatures at which the turboprop propeller and the turbojet nozzle operate and the hundreds of thousands of hours of propeller operation, during which a considerable amount of debugging has occurred. While no supporting evidence can be presented as to the relative state of development of all the control and operating elements of the two types, it seems probable that turboprop engines with adequate propeller and interconnecting controls are more likely to be readily available to the airlines than turbojets with variable nozzles and augmentation.

The dual-compresser turbojet introduces the problem of driving the compressors at different speeds and further complicates the control problem. Not much is known of the fanjet, but its problems appear to be on the order of those of the turboprop rather than the turbojet with variable nozzle. Airline operators may prefer simplified controls with some manual pilot adjustments to the more complicated fully automatic types now under development for all turbine engines.

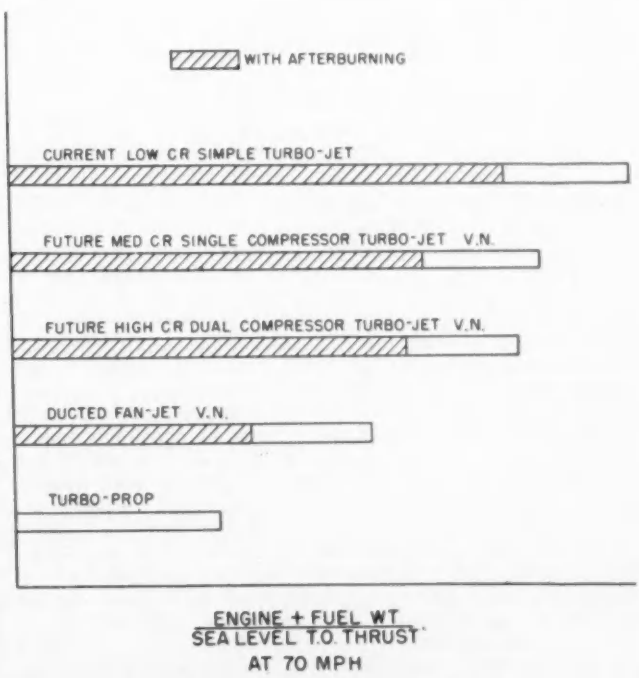
In addition to the background on propellers and their controls, former reciprocating engine manufacturers have a long experience with reduction gears which is directly applicable to turboprop engines. While the higher gear ratios introduce some problems, the virtual elimination of torsional vibration compensates. Experience on turboprop reduction gears, even with high input-shaft speeds, has been very satisfactory to date.

A further point in the case for the turboprop engine is the posibility for future development of this type of engine. It is generally recognized that continued development of turbine-type engines depends largely on increasing the allowable maximum gas temperatures. Both new materials and internal cooling or combinations of these show promise of reasonably rapid application. Many people do not appreciate the fact that there is a major difference in the way such temperature increases affect the turboprop engine as compared to the turbojet.

Fig. 5 shows the effects of an increase in turbine inlet temperature on thrust and specific fuel consumption of a turboprop and a turbojet. It will be noted that the power of the turboprop increases rapidly with higher temperature due to the increased output per pound of air used. This turboprop power can be absorbed efficiently either by increased propeller power coefficient or propeller diameter. The percentage gain on the turbojet is lower due to the less efficient high-temperature jet. In the case of the turboprop engine, the specific fuel consumption decreases steadily with higher temperature. With the turbojet, specific consumption increases at both maximum and cruise thrusts. In other words, to make good use of higher-temperature operating limits, much more redesign is needed in a turbojet engine than in a turboprop. With future allowable-temperature increases, the turboprop will increase its present advantage in both take-off power and low specifics at cruising altitude as long as the airplane operates in the subsonic region.

An important point in the case for the turboprop engine in this country is the availability of at least two sizes of engines which were designed basically for the Navy to perform certain missions which could not be performed as well by reciprocating engines of the sizes available. Due to their light weight and size, the turboprops can be installed in practically all of the postwar fleet of military cargo and transport aircraft and in addition in similar commercial airplanes with an appreciable net gain in performance and operating economy. The difficult prototype airplane problem is solved to the extent that prototypes can be equipped with turboprop engines at the cost of nacelle changes. One such conversion is being made by General Motors on the Convair 240 using two single-turbine Allison 501 Model engines primarily for flight test debugging, control development, and development of operating techniques and features to provide a well rounded military or commercial cargo and transport powerplant.

Within the next year, it can be expected, the Allison Model 500 (Navy T40) will have flown in two or three airplanes and the Model 501 (Navy T38) in one cargo aircraft in addition to the B17 flight test bed now being used, so that evaluation of the turboprop engine in this country will be much further along. It would also appear reasonable to expect that more detailed information on these engines will be released during that time. There should therefore at that time be enough information to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SEA LEVEL T.O. THRUST
AT 70 MPH

Fig. 4—Ratio of weight of engine plus fuel for 3500-mile range at 500 mph at 35,000 ft to thrust available for take-off from sea level at 70 mph for various powerplants

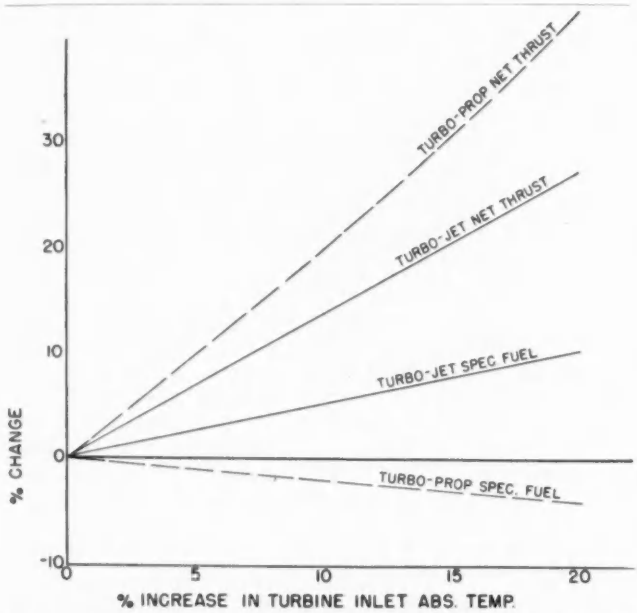


Fig. 5—Effect of turbine inlet temperature on performance at altitude cruise conditions

evaluate the turboprop engine's place in the picture.

In the turbojet field, similar evaluation would have to come from experience with military bombers in this country or from the British and Canadian prototype commercial airplanes. In this country, the turbojet commercial or military transport prototype with suitable powerplants for eventual economic use appears to be at least three years off and possibly more, even though financing of such a prototype by the Government were authorized in 1951 fiscal funds.

Paper on which this abridgement is based is available in full in multilithographed form from SAE Special Publications Department. Price 25¢ to members; 50¢ to nonmembers.

Excerpt from Discussion

—Christopher Dykes

Chief Engineer (Development)
British Overseas Airways Corp.

I would like to confirm that the choice between turboprops and turbojets is by no means confined to the question of speed, as some people have indicated in the past. There are a number of operational and commercial factors.

I believe that the turboprop and the turbojet will be found to have essentially complementary applications, as they have quite different characteristics. The speed difference is linked with large differences in design, which should result in widely different fare levels. The choice depends upon what you seek to do. If you want the highest possible speed, then a turbojet is the obvious, and in fact the only, answer. However, because the percentage loss in speed due to any increase in drag is 50% greater with a turbojet than with a turboprop, most turbojet aircraft will have relatively small fuselages. For dimensional reasons these do not lend themselves readily to high-density layouts, and I believe the majority of turbojet aircraft will have seating corresponding to present airline standards, for instance, 50 passengers in a DC-6.

The volume-limited maximum payload will therefore not be very high. Moreover, because the reduction in the block-to-block speed due to any extra stop is much greater on high-speed aircraft, resulting in a larger increase in the cost per capacity-ton-mile and so in the fare eventually paid by the passenger, it seems likely that turbojet aircraft will find their best application in long stages, limited only by the aircraft gross weight and the fuel consumption of the engines.

On the other hand, if your object is the carriage of a large number of passengers at the lowest possible fare, then a turboprop is the answer. Such an aircraft would have a relatively large fuselage and would correspond to coach accommodation. While the speed would be little if any greater than the fastest present-day aircraft, the fare would be approximately 25% less.

There are a number of other important considerations. The first is the maximum operating altitude you are prepared to accept. The wing loading cannot be unduly high if the approach and landing speeds are to be reasonable, so that the indicated speed in cruise will not be very much higher than on present aircraft. To achieve high speeds, it is therefore necessary to go to high altitudes. I understand that some recent design studies made in this country assume that heights of 50,000 ft are commercially practicable. I cannot agree with this assumption. I believe that in doing so we should be trying to run before we could walk. Even at 30,000 to 40,000 ft, the problems of high-altitude flight on a regular basis are sufficiently great to need enormous efforts for their solution. To go at one jump from 25,000 ft right up to 50,000 ft is, I believe, too great a step. Any failure in the cabin pressurization system or any unexpected failure resulting from our inadequate knowledge of structural design would result in disaster. I personally believe that 40,000 ft or so is a good operating limit for present design, even for operation in the 1955-1965 era.

This limit of altitude weights the scales a little in favor of the turboprop.

Contrary to some recently expressed opinions concerning runway-length requirements, I do not believe that we will have very much difficulty in the landing condition. My reasons for this are (1) relatively low wing loadings are desirable anyway in order to maintain good operational performance with one engine out under fairly high temperature conditions, (2) the high fuel consumption of turbine aircraft, particularly turbojets, means that there will be a wide difference between take-off and landing weight, and (3) improvements in air traffic control, which are already overdue and which are essential for turbine aircraft, should greatly reduce the weight of reserve fuel which must be carried. For all these reasons, the landing run should be relatively short, though we may still see tail parachutes. I think the problem of securing an immediate increase in power in any balked landing may be more serious.

Detailed examination of a world-wide network of routes has shown that the take-off problem will be more serious on turbine aircraft, and particularly on turbojets with cruising altitudes below 40,000 ft. If long runways are available, as for instance on the route between the United States and South America or across the Pacific, then turbojet aircraft can and should operate at a substantial profit. On other routes, particularly in Asia and Africa, this is not true, and operation of turbojet aircraft may have to be confined to a few main routes for some years to come.

To sum up, therefore, I believe that turboprops should be applied to relatively large aircraft, carrying large numbers of people in coach accommodation, over short and medium-length stages, at speeds of 300 to 400 mph. The fares should be very substantially below those at present prevailing.

I believe we shall also need turbojet aircraft to carry the first-class traffic and mail at high speeds over relatively long stages. This means that the gross weights of turbojet aircraft will tend to be the higher.

The fare differential between the two types should be sufficiently large to attract two classes of passengers, so that both types will be required.

In fact, there is a case for the turboprop and the turbojet!

Torque Converters Pay Off In Earthmoving Machinery

EXCERPTS FROM PAPER* BY

E. F. Norelius, Consulting Engineer, Allis-Chalmers Mfg. Co.

* Paper "Infinite Ratio Transmissions," was presented at Earthmoving Industry Conference, SAE Central Illinois Section, Peoria, April 11, 1950.

THERE is a place for an infinite ratio transmission in practically all heavy-duty earthmoving equipment because it makes for most efficient engine operation and simplifies the operator's job.

Machines with which a torque converter would be advantageous include crawler tractors with related equipment, various rubber-tired units, and shovels. Tractor use covers pulling of self-loading scrapers, blade and elevating graders, various type wagons, and military equipment. The tractor may be equipped with various type front blades and become a bulldozer, stumper, pusher, or shovel. As a pusher, it may work in a team with one or more other tractors.

Rubber-tired tractors may be self-loading scrapers, bulldozers, heavy-duty trucks, or motor patrols and power graders. Tractors also may be equipped with various winches for logging and in oil fields. Other heavy-duty equipment for which torque converters are suited are digger and drag line shovels and mining machinery.

In each of these machines, the desired transmission performance characteristics are:

1. A stall torque ratio (maximum) suitable to the job with engine running at maximum torque speed.
2. Under operating conditions, output rpm times output torque should remain constant, both varying to suit load demands.
3. Output rpm times output torque divided by input rpm times input torque should be near unity, or equal to the best gear transmission.
4. Input rpm should remain substantially constant within working range.
5. Sufficient usable range of torque output to torque input for all uses.
6. Means for controlling output rpm when desired.
7. Means for controlling rate of change of output rpm when desired.

These characteristics accrue the following benefits:

1. Smooth starting of load at all times.
2. Life of engine clutch will be greatly increased since load is now accelerated through action of transmission.
3. Engine cannot be stalled. Pull or output torque is obtained with the load stationary, the same as with a draft animal.
4. Engine operates at its best efficiency.
5. It is not possible to lug engine down to injurious speeds.
6. Maximum pull is available at all times.
7. Operator judgment is largely removed as regards gear selectivity.
8. Perfect teaming of several tractors is possible.

Now let us see how gains such as these are made possible using torque converter transmissions.

Fig. 1 is a study of performance curves of a step gear transmission. A study was made of several

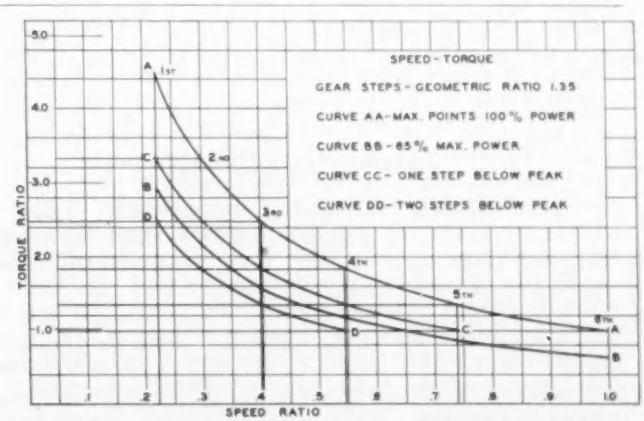


Fig. 1—Speed-torque performance curves of a step gear transmission

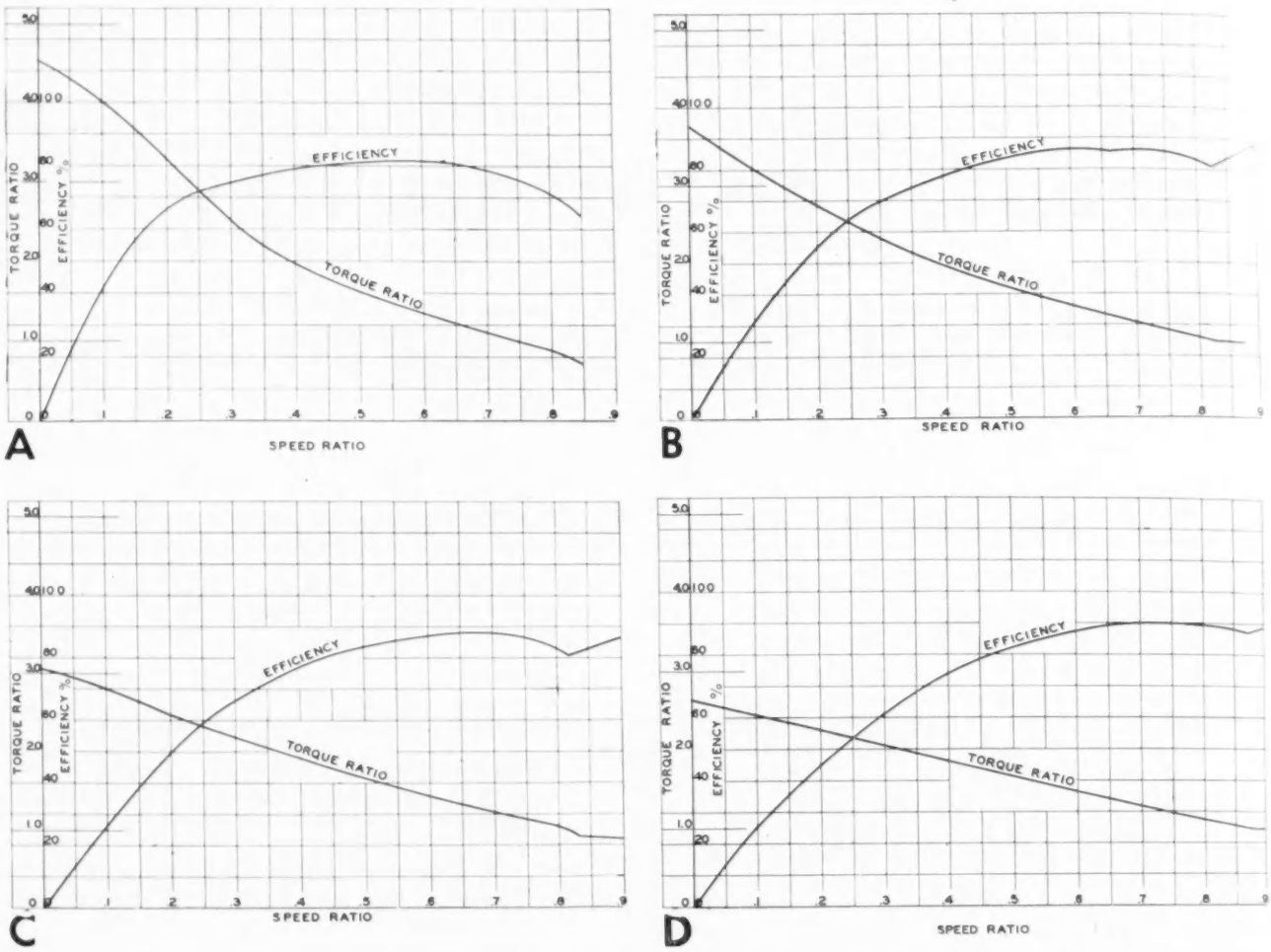


Fig. 2—Performance curves of four different torque converter transmissions. The converters of B, C, and D have overrunning reaction members

heavy-duty transmissions. The average ratio of 1.35 was determined as the step from one gear to the next, and the curve is based on this figure.

A machine equipped with such a transmission in the hands of an operator cannot, of course, operate to its full capacity, since it is left to the judgment of the operator as to the gears in which he operates. But more than that, there are only six points on the top curve AA, and these are the maximum capacity points of the unit. Therefore, it would not be possible to operate at any time, except for momentary peak demands, on the maximum curve AA.

Average at 65% Capacity

Percent of this maximum point possible to operate depends on the job, the type of work, and the load variation of that job. But from a study of a broad run of jobs, it appears that 65% of this maximum is a good average figure. In Fig. 1, curve AA and the second curve BB, which is 65% of AA, are shown. Curves CC and DD are drawn through the points one and two gear steps below the corresponding points of AA.

This chart gives a fair idea of where in a step gear transmission the average operator works. He is forced to work at this low power factor because the load varies so rapidly he cannot shift gears to suit the instantaneous loads.

Fig. 2 shows typical primary performance curves of four different makes of torque converters. Those represented by Fig. 3 B, C, and D have overrunning reactors. These automatically convert to a fluid flywheel when output torque equals input torque, at less efficiency than the conventional fluid coupling.

Fig. 3 shows again speed-torque relation. Here, curve AA and BB are reproduced, AA as before being 100% engine power and BB 65% engine power. Between these two is a speed-torque curve developed by using one of the primary torque converter curves. This then is a typical performance curve when using a converter.

Fig. 4 is a curve based on several makes of torque converters, showing relation of top efficiency and stall torque ratio. It indicates that starting with a fluid clutch, which is one to one ratio, and with an increasing torque ratio there is a drop in efficiency. It becomes a question then as to what stall torque ratio should be used. This will vary of course as to type of vehicle and job to be performed.

Further development, no doubt, will raise the

level of this curve. The lower the stall torque ratio and the higher the efficiency, the narrower, in general, the operating range; and more gear choices are required to obtain the range required for the vehicle and the job.

Fig. 5 is a dimensionless curve in some respects, but the two extremes are well known. If there existed an infinite ratio transmission with sufficient range so that no gear shift were required, then engine would operate at maximum power. Also, as before, if the vehicle (and earthmoving tractors are referred to here) is equipped with an all-gear transmission, the curve hits the 65% line. These two points must join as number of gear shifts are increased, due to a decrease of the torque ratio within the operating range.

More Work in Bulldozing

Fig. 6 shows two tests made, indicating load variation when bulldozing. These cover the complete cycle, the working load forward and the reverse load. On this type of work, the torque converter indicated about 22% more work than a step gear unit.

Fig. 7 is a comparison of a torque converter transmission and a full-geared transmission. These functions are dimensionless in some respects, but the extremes can be quite well analyzed.

These lines are drawn on the basis of two functions—"Power Factor" and "Load Variation Factor." Power Factor as used here is the average horsepower delivered to the transmission times 100, divided by full load net engine horsepower available.

$$PF = \frac{HP\ (delivered) \times 100}{HP\ available}$$

Load Variation Factor as used here is the peak or maximum load, as indicated by Fig. 6, minus the average load divided by maximum load, times 100

$$LVF = \frac{(Max.\ Load - Average\ Load) \times 100}{Max.\ Load}$$

No effort will be made to explain how the upper and lower points were obtained, except to state that

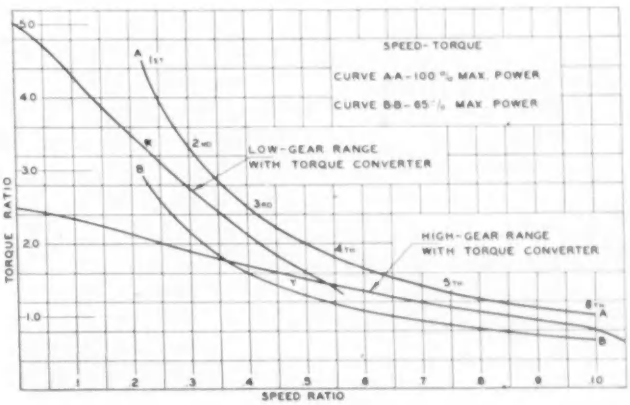


Fig. 3—The torque converter performance curve lies between the 100% and 65% maximum engine power curves

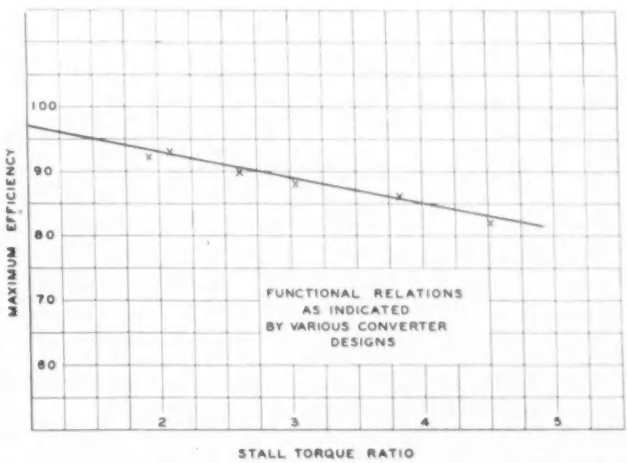


Fig. 4—Functional relations as indicated by various converter designs

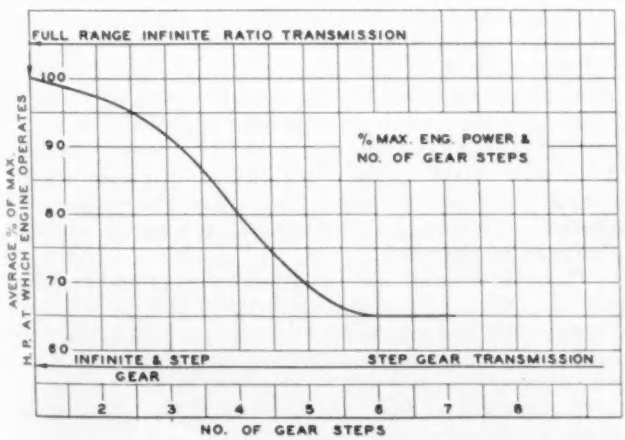

FULL RANGE INFINITE RATIO TRANSMISSION
AVERAGE % OF MAX. H.P. AT WHICH ENGINE OPERATES
% MAX. ENG. POWER & NO. OF GEAR STEPS
INFINITE & STEP GEAR
STEP GEAR TRANSMISSION
NO. OF GEAR STEPS

Fig. 5—As the number of gear steps combined with a torque converter increases, maximum engine operating power departs from 100% (the case with a full-range, infinite ratio transmission), and approaches the 65% point (the figure with a step gear transmission)

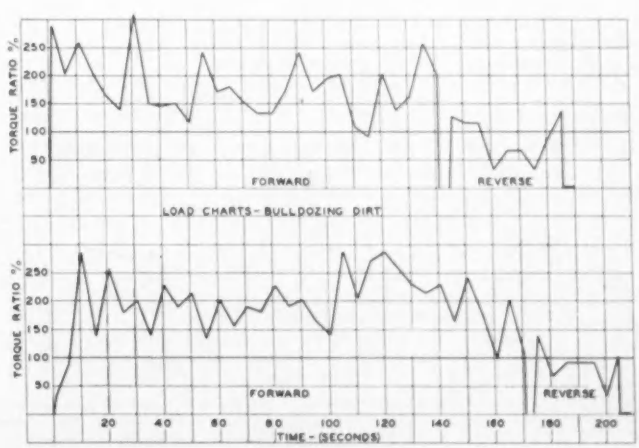


Fig. 6—Record of load variation in bulldozing tests

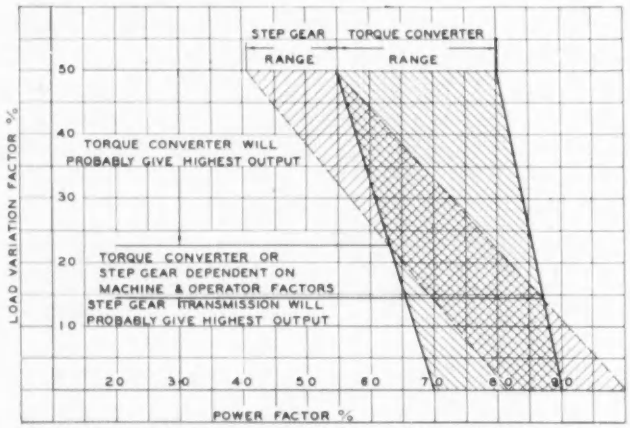


Fig. 7—How torque converter and full geared transmissions compare

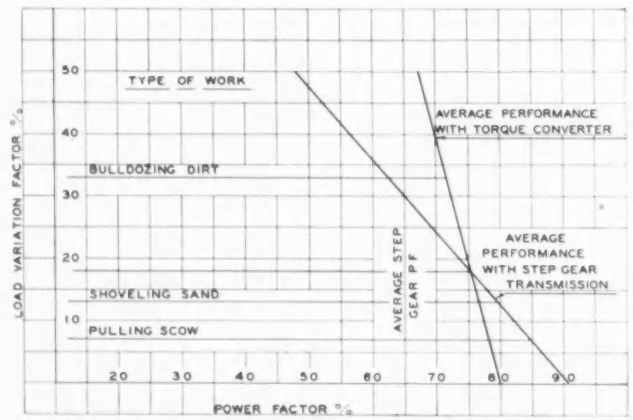


Fig. 8—Torque converter and step gear transmission compared for various earthmoving operations

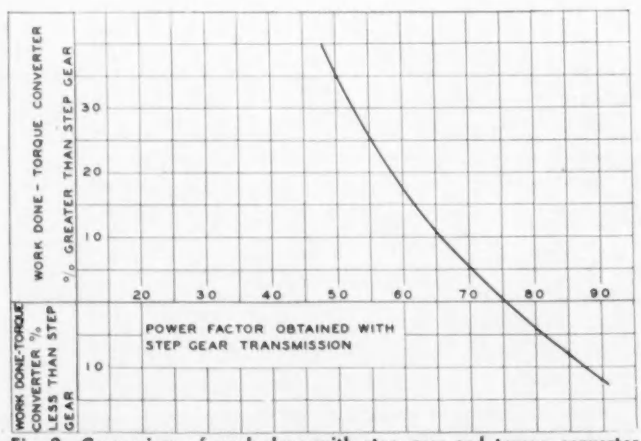


Fig. 9—Comparison of work done with step gear and torque converter transmissions

if the Load Variation Factor is zero, which means that load demand is absolutely constant, and if a step gear transmission just matches this load in one of the gears, then the power factor will be 100. If, however, the load is too great for this selected gear, then it is necessary to operate one step lower on the gear train and the power factor will be in proportion to the gear steps, giving due credit to increased torque as the engine speed is pulled down.

Plotting Performance

This gives the two extreme lower points for the step gear transmission. Similar reasoning with embellishments has been used for all the other upper and lower points. From these, an average performance line can be drawn for both the torque converter and the step gear transmissions.

In Fig. 8 these two average lines have been reproduced and lines have been drawn in, showing location of the bulldozing tests in Fig. 6, also a test pulling scow or skid. The Load Variation Factor was computed from the test curves by the formula.

Fig. 9 is a recapitulation of the data covered and revealed in the former figures. This curve gives a very clear conception of the comparison of a torque converter and a step gear transmission.

It is believed that all these data and curves are built on a conservative basis, well within what might be expected of a torque converter.

Other Converter Merits

There are other factors that need to be emphasized, some of which build toward the performance shown; but some also add to machine life and to favorable operator reaction and owner acceptance.

Removing operator judgment as to gear selectivity makes it possible for him to take better advantage of the traction available. Mention has been made of the life of clutches. Years ago a set-up was used for making comparative tests of steering clutches. This was done by locking the output side of the clutch, allowing the engine to high idle against the governor, then engaging steering clutch pulling engine speed to a set low speed, disengaging clutch to free engine, allowing it to again return to high idle speed. This operation was repeated at definite intervals.

This same test was tried with a torque converter in the transmission line between engine and clutch. This operation did not measure up to a test on the clutch. What happens is not too clear; but it is presumed that clutch was fully engaged before major load was evident, and, therefore, the converter went into the stall condition with no material slippage at the clutch.

There is no definite judgment yet as to the effect on the balance of the transmission train; but with these known factors it must be substantial. Experience to date indicates that transmission life is not shortened by the higher power factors obtained with a torque converter because of the elimination of shock loads.

This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

Reversing Props in Flight Promises Safer Air Travel

Because it permits airplanes to descend quicker . . .

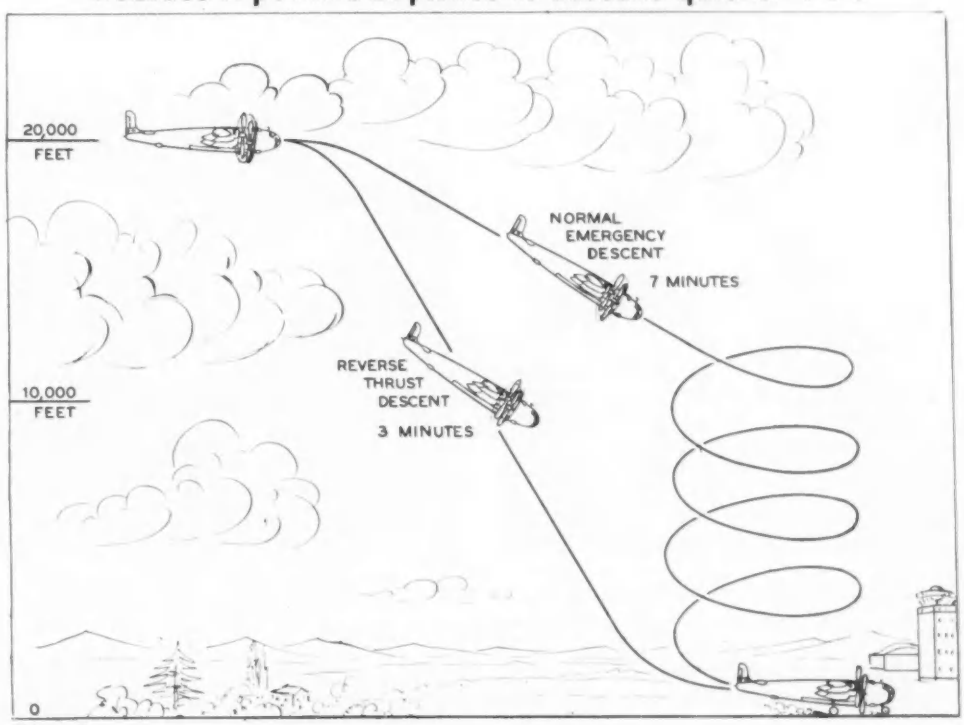


Fig. 1.

EXCERPTS FROM PAPER* BY

Herbert O. Fisher, Chief Test Pilot, Curtiss-Wright Corp., Propeller Division

* Paper "Investigation of Reversing Propeller Pitch on a Multi-Engine Aircraft in Flight" was presented at SAE National Aeronautic Meeting (Spring), New York, April 17, 1950.

REVERSING propellers in flight permits faster descents for emergencies without danger to the aircraft or discomfort for passengers, tests with a C-54 showed.

Most important use of reverse pitch in flight is for emergencies such as fire, cabin depressurization, and personnel accidents. For situations like these, reverse pitch operation opens new possibilities in saving passengers, crew, and aircraft.

Fig. 1 shows that a descent from 20,000 ft under standard rate-of-descent, reversing pitch on four engines, can be made in 2 to 3 min. The time difference would be still greater in descents from higher altitudes.

Fatalities are very likely during a scramble or emergency bailout on military aircraft operating between 40,000 and 50,000 ft. At this moment gloves, face masks, and other clothing must be on and suitable for jumping out at high speeds into temperatures of –50 to –75 F to prevent instant freezing. Possible fouling of oxygen equipment and technique requirements for each individual add complications to emergency bailout at high altitudes.

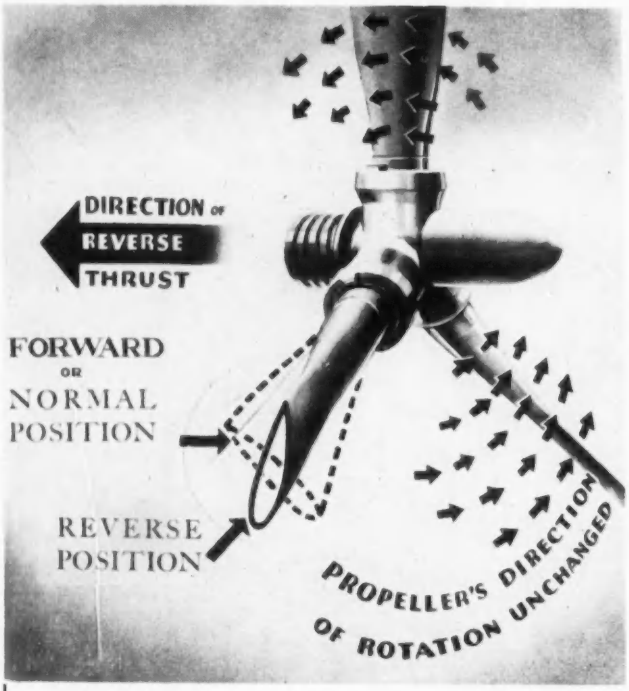
In case of cabin depressurization, personnel cannot survive the rare air and low atmospheric pressure between 35,000 and 50,000 ft unless pressurized oxygen equipment is used. Length of time one can remain conscious at these altitudes without oxygen

Effect of Reverse Propeller Thrust

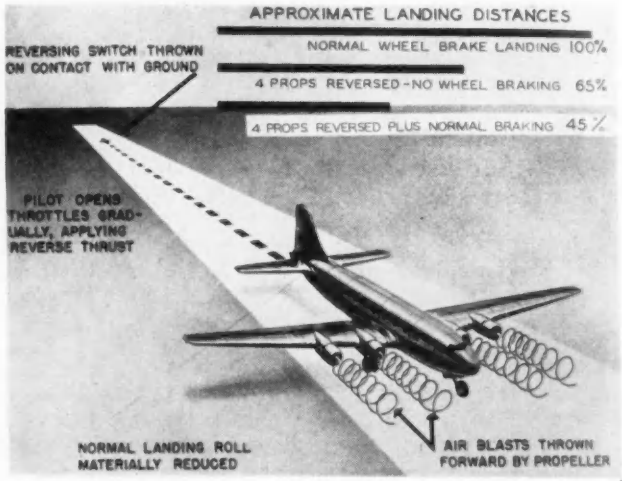
The illustration at left shows how reverse propeller pitch differs from normal pitch.

A propeller blade in normal forward pitch makes a positive angle with the propeller's plane of rotation. The blades literally "pull" their way through the air. In this case, exerting forward thrust accelerates the airplane.

When the blade pitch is reversed, they make a negative angle with the plane of rotation of the propeller. They exert a rearward thrust and decelerate the airplane.



This deceleration imparted by reverse pitch has been used to reduce landing run of aircraft. The illustration at right shows the reduction possible with a typical four-engine airplane. Reverse pitch for landing is particularly useful where a landing approach has been overshot, where runways are slippery, or when the aircraft brake system has failed.


APPROXIMATE LANDING DISTANCES
NORMAL WHEEL BRAKE LANDING 100%
REVERSING SWITCH THROWN ON CONTACT WITH GROUND
4 PROPS REVERSED - NO WHEEL BRAKING 65%
4 PROPS REVERSED PLUS NORMAL BRAKING 45%
PILOT OPENS THROTTLES GRADUALLY, APPLYING REVERSE THRUST
NORMAL LANDING ROLL MATERIALLY REDUCED
AIR BLASTS THROWN FORWARD BY PROPELLER

equipment is critical. Descent below 10,000 ft is mandatory unless oxygen equipment is used immediately.

Very high descent rates, made possible with reverse pitch propellers, permit rapid enough altitude reduction to prevent anoxia fatalities in most cases.

Rate-of-descent controllability with reverse pitch propellers may also be applied to traffic let-down operations. Present patterns and procedures for weather stacking may not lend themselves to accelerated let-downs by this method; but a more immediate use would be for altitude loss at terminal points following long-distance, high-altitude flights.

Such flights in the 20,000 to 45,000-ft region must now begin their descent as far as 200 miles from their destination. The same flights could deter let-down to within a short distance from destination with reverse propellers. This would permit continued and more efficient high-altitude cruising. It could possibly decrease time necessary to fly in icing or turbulent weather conditions at lower altitudes.

Rates-of-descent may be closely controlled for let-down procedures by the number of propellers reversed and airspeed selected. Table 1 lists the various rates with a C-54 airplane under different conditions. A wide range of descent rates may be selected. These rates can be closely maintained by use of power, rpm, indicated air speed, and various engine combinations shown.

From flight tests emerged a procedure for reversing propellers and a picture of the phenomena that occurred. Reversing two propellers on one side, the most critical condition, was easily controllable. Reversing all four propellers at once on the C-54 test airplane was perfectly safe and its effect hardly noticeable.

Reversing Individual Propellers

The flight program called for reversing No. 3 propeller first at idle power and at 115 mph ias. This was to be followed by additional reversals at the same zero power, but increasing airspeed in 15 mph increments until 205 mph was reached. Then airspeed was held constant at each of the previously selected values, while reversals were made increasing engine power by increments of 5 in. manifold pressure each time.

As power and airspeed increased, it quickly became apparent that engine rpm momentarily increases as propeller blades change position from forward to reverse pitch. This momentary rpm rise

becomes a limiting factor for the airspeed, rpm, and power conditions at time of propeller reversal. In the case of the C-54 it was found that the best entry condition was between 125 and 200 mph, with the propellers windmilling at around 2000 rpm. Using these values and procedures we did not exceed any engine limits.

Application of excess power during the first half of the reversing cycle is very conducive to overspeed conditions, so that it is best to accomplish the reversals at idle power settings.

The above condition of rpm surge may be attributed to two factors—high powers and higher airspeeds. In the case of higher powers, as a propeller moves from forward to reverse pitch, it must pass through the zero blade angle. Any amount of power at this point will simply be rotating the engine with no aerodynamic load on the propeller blades.

In the case of airspeed effect, the aerodynamic windmilling force of the airstream on the propeller blades increases rapidly as the blades move through the lower positive pitch region. This windmilling force further creates an inertia in the rotating propeller which increases rotational speed as the blades reach zero pitch position.

Anti-Windmilling Required

Reversal using a constant speed feature in reverse does not require any unusual pilot technique, because the governor will adjust the reverse blade angle so that normal engine rotation is maintained even at idle power. However, if only the present ground type reversing equipment is used, as was on our initial C-54 tests, an important problem does arise. Once the propeller starts for the reverse pitch position, it goes directly to the high reverse fixed angle. Therefore, considerable reverse windmilling effect is encountered almost instantly. In this case, alert throttle use is required.

The throttle must be at idle when starting reversal, but must be quickly advanced as the blades reach reverse position to prevent losing the engine from windmilling backwards. If this reverse windmilling condition does occur, the propeller must then be unreversed as soon as possible to prevent engine damage which may result from reverse rotation without proper lubrication.

The probability of losing engines to backwards rotation and the other possible consequences of this condition make it inadvisable and impractical for any reversing in flight to be attempted with present ground-type reversing equipment.

Considering then only the case where we have constant speed feature in reverse, engine and propeller reaction follows a trend as shown in Fig. 2, a typical record of C-54 reversal.

Before reversing at ias (indicated air speed) of 180 mph, it is seen that the power is zero, rpm is at 2000 for entry, and propeller blade angle at low forward pitch position of plus 17 deg. When actuating reverse, the blades moved at the approximate rate of 10 deg per sec through the zero blade angle. At this point the rpm reached its peak of 2400 rpm (peculiar to this particular power and airspeed condition only) and with power still at zero. Within the next half second, as the blades move into the reverse pitch region, the rpm starts to decrease. If power was permitted to remain at zero, the constant speed feature in reverse would set the blade angle near zero position and permit the propeller to turn at an idle rpm, depending on the forward velocity of the airplane.

However, it is desirable to apply some reasonable amount of power after reversal to maintain normal engine temperatures. Therefore, we operated at between 10 and 15 in. manifold pressure, as shown in the curve. It is seen that as this low power is applied, the rpm and blade angle stabilize at conditions shown.

Once in reverse, and having constant speed equipment, operation of the propeller is the same as in forward; rpm, engine power, and airspeed may all be varied to obtain an infinite number of combinations. This ability to attain a variety of conditions is very important for reverse operation. The smoothest descent and desired reverse thrust may then be selected.

Having determined the reversing and unreversing procedure with No. 3 engine only and before reversal of all four propellers simultaneously the next problem was what might be the effect on airplane control if an outboard or two propellers on one side were reversed.

Primary concern in reversing propellers on one side was the amount of airplane yaw induced by the increased drag of the reverse thrust.

With the C-54, reversal of one inboard engine only, up to and including maximum airspeed, rpm, and power conditions did not produce excessive yaw. Such reversals were accomplished without much trim or rudder control application. They had about 5 deg momentary effect, and a steady 3 deg under optimum stabilized conditions.

Yaw Induced Not Critical

Reversal of an outboard propeller has a correspondingly greater effect on the yaw introduced. Initial yaw at reversal was experienced as high as 10 deg, with a steady yaw of 7 deg apparent under stabilized reverse conditions.

The most critical condition of yaw occurs when two propellers on one side only are reversed. The drag effected by the reversal of two propellers on one side immediately required counter-yaw control action with rudder application. These conditions,

Table 1—Various Rates-of-Descent of a C-54 with Reversed Propellers

Number of Propellers Reversed	Indicated Air Speed	Rpm	Power (in. hg)	Rate of Descent (fpm)
4	200	2000	15	11,000
4	175	2000	15	8,000
4	150	2000	15	6,000
2 (Outboard Propellers)	200	2000	15	6,000
2 (Outboard Propellers)	175	2000	15	5,000
2 (Outboard Propellers)	150	2000	15	4,000

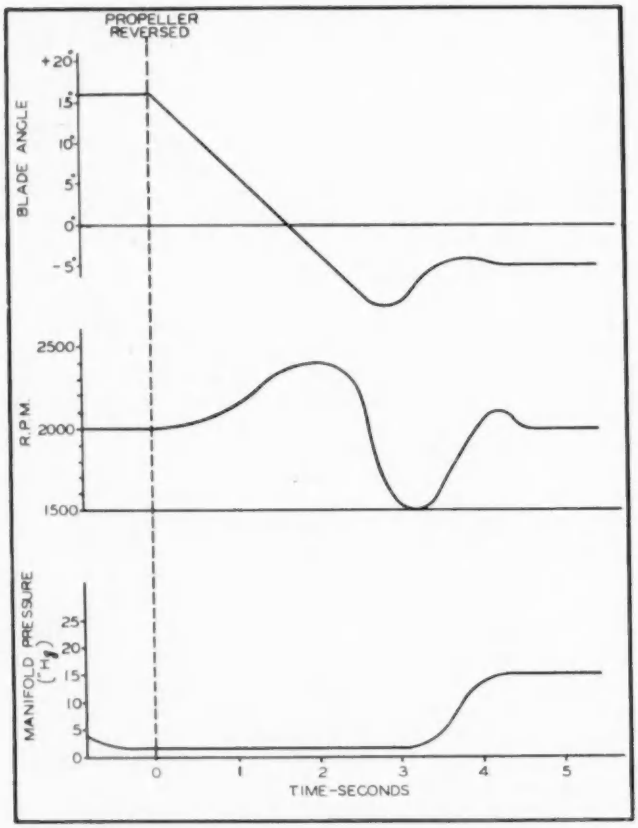


Fig. 2—What happens during a typical propeller reversal of a C-54 airplane at an indicated air speed of 180 mph

however, proved to be well within handling limits for the C-54. Hands-off airplane control for straightline flight descent under all these combinations was possible with trim tab correction.

Under critical reversal conditions as described, the airplane was flown at near-stall speeds, steep turns, and various other maneuvers. These tests ascertained that airplane controllability was safe and effective for all conditions expected to be encountered.

Four-Propeller Reversal

Now we were prepared to apply reverse pitch to all four propellers simultaneously on the airplane and investigate the aspects of this operation. There were a number of items to be observed during this testing, the most important being as follows:

1. Airplane and propeller control handling,
2. Airplane, propeller, and engine reaction,
3. Controllability and rate-of-descent in reverse,
4. Personnel effects and reaction, and
5. Recovery.

The majority of all the C-54 tests were started at 15,000 ft. This gave sufficient altitude to check rapid rates of descent over reasonable distances. It also permitted freedom of crew operation without use of restricting equipment such as oxygen units.

The airspeed, rpm, and power were set to the optimum values as determined by our initial preliminary testing.

Almost instantaneously as the throttles are moved to reverse position, the rpm rise and fall is accompanied by the sound effect of "paddled" air as the flat blades disrupt and disturb the usual smooth airflow past their surfaces. Simultaneously with the rpm and sound level increase, comes a momentary buffetting or slight shudder of the airplane proper. This vibration of the airplane resembles the very early prestall buffetting encountered in many type aircraft.

All the reversing effects become less and less impressive as the operation is repeated. Individuals who have flown in the C-54 and experienced a reversing demonstration for the first time have all been in agreement that this relative effect is of minor consideration. The buffetting effect occurs at the moment of reversal and disappears in about 3 to 4 sec as stabilized reverse operation is attained. The buffetting was observed to be most apparent in the nose compartment of the C-54, seeming to diminish back through the passenger compartment.

In addition to these effects, airspeed loss at reversal automatically tends to pitch the nose of the airplane down slightly. The level flight deceleration at this point and the vertical descending force is estimated to be in the neighborhood of 1 to 1½ g, depending on airspeed and rate of entry into reverse.

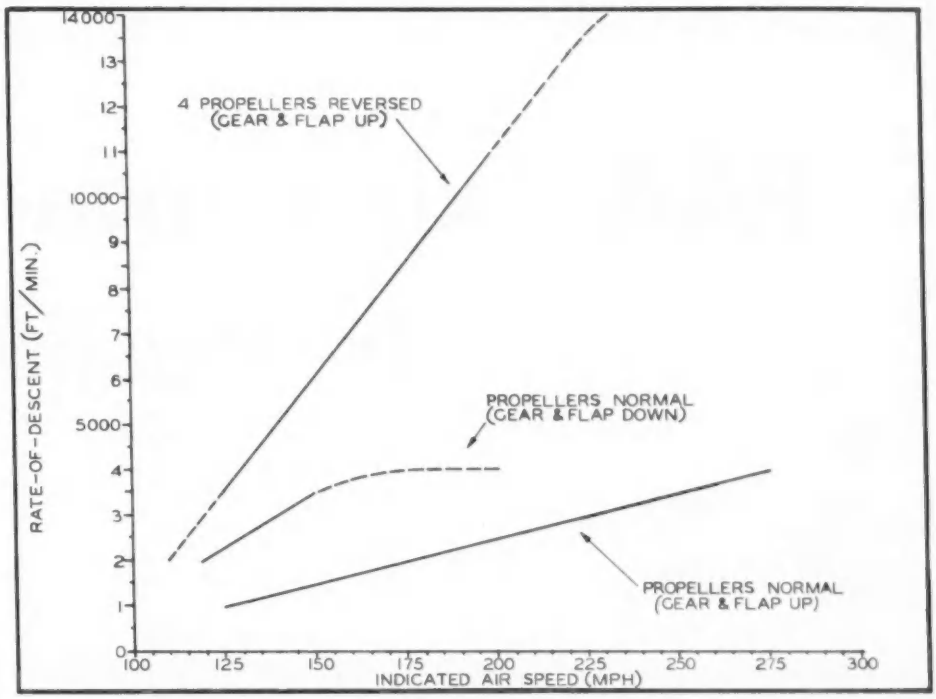
Following the deceleration effects at reverse, the final stabilization of the airplane is a comparatively smooth ride when descending at 2 miles per min. As the airspeed is adjusted to a desired value, the throttles are moved rearward slowly in the reverse power range until suitable power is obtained and at that moment the aircraft assumes a nose down attitude of between 25 and 30 degrees. Testing showed that the rate-of-descent was directly proportional to propeller rpm. An increase in rpm gave an increase in rate-of-descent. However, increasing the rpm to values above 2300 also increased airplane vibration considerably.

With power applications, our flights showed that increases had comparatively little effect on increasing the rate of descent. Power settings throughout the throttle range in reverse were tested and the smoothest operation resulted from using low powers. The optimum setting of 15 in. manifold pressure and 2000 rpm was chosen for the operation and to maintain engine operating temperatures. It was a combination of these rpm and power settings at a dive airspeed of 200 ias that gave maximum rate-of-descent performance under the most satisfactory conditions.

The vibration experienced in the airplane during a stabilized reverse-pitch dive is similar to the low frequency vibration and beat which is sometimes felt in making fast glides with propellers in high forward pitch. The slight vibration or buffetting originates primarily from varying forces on the tail surfaces, as the normal airflow is somewhat disrupted by reversed propellers. Some of the vibration does stem from engine operation and disturbed airflow over the wing surfaces; however, this appears to be minor.

Tail vibration, as may be expected, is mainly excited by the inboard propellers. When only the outboard propellers are reversed, empennage vibration is negligible and overall airplane vibration is consequently reduced. However, with all propellers reversed and the entire range of rpm, powers, and airspeeds operated up to maximum values, the

Fig. 3—Rates of descent of a C-54 compared with and without propeller reversal



stresses in critical airplane structure did not exceed 10% of the manufacturer's allowable at any time.

The minimum or stall speed of the airplane is effected by reverse pitch. With the C-54, the normal stall speed was about 95 mph, and with propellers in reverse, was about 125 mph.

Controllability of the aircraft while descending in reverse was satisfactory and normal in all respects. Though the required column and rudder forces do vary, control movement receives positive and standard response. In addition to the stall tests made with propellers in reverse, airplane handling was investigated with respect to varied banks and turns and all normal multi-engine maneuvers at both maximum and minimum dive angles and rates-of-descent.

Surprisingly enough, the unreversal of all four propellers on the C-54 airplane and recovery to normal flight is a smooth and easily accomplished operation. Even reverse dives at the most rapid rate-of-descent of 11,000 fpm were quickly terminated and normal control in forward pitch was resumed in a matter of seconds.

Rates of Descent

To compare rates for the C-54 airplane, shown in Fig. 3, a number of descents were made with propellers in normal pitch under various conditions. Dives were made at the airplanes maximum placard speed of 275 mph with propellers in low pitch and gear and flaps retracted. Descents also were made with gear and flaps extended at the airplanes placard speed for that configuration of 150 mph.

Rates-of-descent vary with atmospheric conditions and altitude. However the average rate-of-descent for the C-54 airplane, staying within the structural limits, appeared to be about 4000 fpm for the clean dive condition and 3000 fpm for the gear and flap extended.

In contrast with these slower rates-of-descent, our emergency procedures executed today with all four propellers reversed attained rates-of-descent up to 11,000 fpm.

The curve illustrates that the 11,000 fpm rate-of-descent, using reverse pitch, is obtained at a low ias of 200 mph. The present rate-of-descent, 4000 fpm without reverse, requires higher airspeeds up to, and over, 275 mph.

Reversal Excels Top-Speed Dive

In addition to a comparatively low rate-of-descent resutling from the clean dive configuration, diving a large airplane at its maximum placard speed is a critical operation. Air turbulence becomes a limiting factor, introducing possible gust loads on the airplane structure which may well exceed its safety limits. Therefore, it appears that a more effective method of descending rapidly is to reverse propellers in flight.

Adoption of this procedure, at least as an emergency measure, appears at the moment to be promising. At present, further flight tests on B-50 and B-36 aircraft are scheduled by the Air Force. The satisfactory completion of such testing may well prove to be a most significant advance in aircraft safety. It is hoped that through these tests Curtiss has conducted, the procedure of reversing propellers in flight will prove its use in saving passengers, military crews, and aircraft and make for more efficient flight operations.

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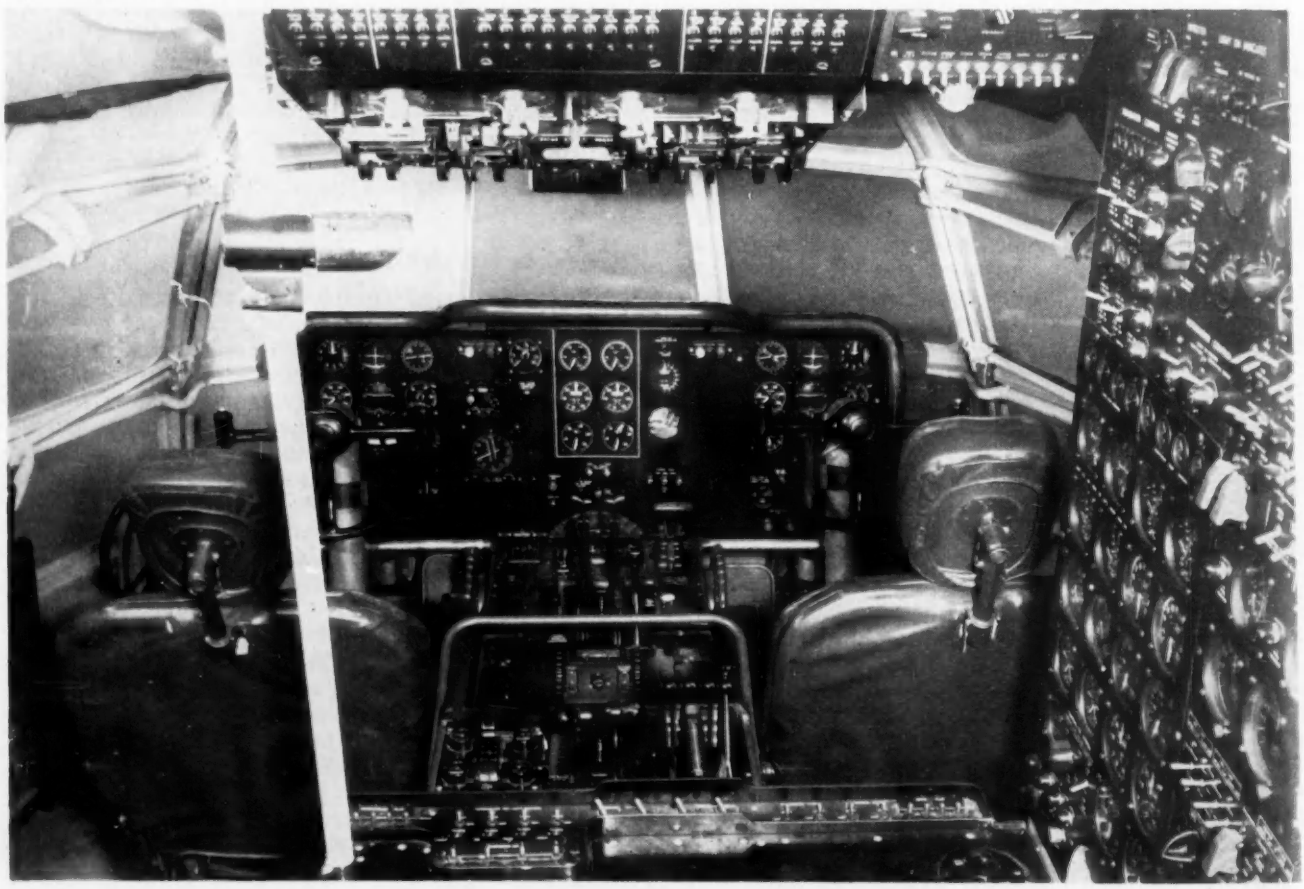
PAA Experience Proves Is Realistic and

THE flight simulator after a year has shown Pan American Airways that it provides realistic training—and saves money.

The B-377 Flight Simulator cockpit is an exact replica of the actual aircraft cockpit, duplicating the stations of the captain, first officer and flight engineer. These stations are furnished with all parts, instruments, switches, circuit breakers, and controls installed on the aircraft. These were supplied by the Boeing Airplane Co. and instrument manufacturers. Fig. 1 illustrates these flight stations.

To simulate navigation problems requiring use of radio ranges, ILS systems, and ADF homers, two

Fig. 1—Flight stations in simulator



Flight Simulator Economical

EXCERPTS FROM PAPER* BY

Scott Flower, Assistant Chief Pilot, Pan American World Airways System

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Curtiss-Wright automatic ranges are supplied. These two units are capable of duplicating the entire navigation and let-down procedures for the New York area, and as a result can duplicate the traffic and let-down problems of most areas of the world. Also included is a communications control panel for the instructor which indicates the frequencies being utilized by the flight crew, as well as such equipment as controls for locating ADF markers. PAA experimented with an altitude recording device, which is available for the trainer but is not included in the present model.

Located to the right rear of the trainer is a piece of apparatus referred to by the flight crews as the "hell box." It is designed to introduce various flight difficulties into the simulator. The difficulties encountered range from fires, both fuselage and engine, to such items as generator overheat indication. This "trouble panel," as it is more conventionally termed, is also capable of depleting the fuel supply from any tank at an abnormal rate as well as enabling the instructor to change gross weight and center of gravity location at will. Fig. 2 shows this panel.

Fig. 3 illustrates the entire simulator interior, giving the relative positions of the various units described above. The rear enclosing panel, which includes the entrance door, has been removed for this picture.

The working heart of the simulator consists of four cabinets that include (1) the power supply, (2) the aerodynamic functions of the simulator or flight cabinet, (3) Numbers 1 and 4 engines, and (4) Numbers 2 and 3 engines. With the exception of the power-supply unit, they are electronic computers. All of these units are located in a separate room to isolate the heat dissipation. Fig. 4 shows the arrangement of the simulator presently utilized by PAA.

As can be readily seen, the Curtiss-Wright Flight Simulator is an intricate piece of apparatus and an advanced type training aid, to be approached as an aircraft, *not* as a trainer, hence its name simulator.

The brains of the flight simulator are located in the four cabinets. In three of these cabinets can be found an array of servo mechanisms and their amplifiers which are instantly, automatically, and continuously solving differential equations relative to flight and engine power. This incredible performance is the result of efforts expended by a highly skilled group of aerodynamicists and electronics engineers under the direction of Dr. Ralph Dehmel of Curtiss-Wright. These men have reduced the various aerodynamic equations of flight and thrust into terms which allow the manufacture of contoured potentiometers for producing the desired results in the servo units.

Examination of the engine cabinets reveals, for example, a computer for each engine for the effect of outside air temperature, rpm, manifold pressure, bmep, cowl-flap setting, oil-cooler setting, and intercooler setting on that particular engine. A look into the flight cabinet reveals a computer which is constantly computing the flight attitude from the configuration of the airplane and transmitting signals back into the cockpit instrumentation as airspeed, angle of bank, pitch, and yaw. In this flight computer are servo mechanisms for computing such functions as angle of attack, rate of climb, altitude above sea level, altitude above ground, true airspeed, and others. All these servos are related one to the other, and many receive their controlling impulses from perhaps four, five, or six other units.

For example, when the flight engineer opens or closes the cowl flaps for any engine in the simulator, the cowl-flap position is indicated on his instrument panel, and, in addition, a signal is transmitted to the engine cabinet. The cowl-flap servo then sends out impulses which vary the airplane drag, yaw, attitude, and airspeed, and the temperatures of that particular engine.

The power supply for the simulator and the three computer cabinets is derived from the power supply cabinet. A 220-v, 60-cycle, three-phase line is brought into this cabinet from an outside source and is converted into whatever voltages are needed

throughout the simulator. These voltages vary from 320-v direct current down to 2.5-v alternating current. The total power consumption averages approximately 11 kva.

Transition Training

The problem of transition training from one type of aircraft to another is not one of teaching the individual crew members to fly but teaching them to fly a particular type of aircraft with emphasis on how the new aircraft varies from the types previously flown. The major problems involved, therefore, are

1. Complete cockpit familiarization so that the crews will be so familiar with the physical location of each control and switch in the cockpit that it can be located instantly and without error during an emergency situation.
2. The crews must be thoroughly familiar with all procedures and flight characteristics peculiar to the type of aircraft in which transition is being made. Their proficiency must be such that the procedures become almost automatic, and the airplane is subconsciously flown correctly when the crew is faced with an emergency situation.
3. Emergency situations must be presented with the repetition necessary to make the solving of the problems attending the emergency dependent upon reaction rather than a prolonged thought process.

In aircraft for which there is no flight simulator, it is necessary to attain these objectives on the aircraft itself. Many drawbacks attend this type of program, such as

1. Unavailability of aircraft for training due to scheduling requirements.
2. Training delays due to inclement weather.
3. Mechanical delays.

Fig. 2—Instructor's panel

4. Traffic delays at busy airports.
5. Dependence upon outside radio aids such as ranges and ILS installations which are quite frequently inoperative when that type of training is desired.
6. Danger of damage to equipment while executing unusual maneuvers and, of course, wear and tear on aircraft.
7. Expense of such a program where a large number of pilots is involved.

During the transition program from flying boats to the Constellation where the aircraft only was used, the average time required per pilot was 12.6 hr, which means that requirements for complete crews would be 25.2 hr.

With the use of the B-377 flight simulator in conjunction with the Stratocruiser training program, it has been possible to attain the above-mentioned objectives in a more efficient manner by utilizing the simulator to such an extent that only a modicum of actual flight training is required. We have been able, with the aid of this trainer, to qualify pilots on the aircraft in 4 hr of actual flight time, for a total of 8 hr per crew. Fig. 5 shows a plot of time required for check out by both methods of training for the same pilots, on Constellation and B-377 aircraft. The line drawn at 10.5 hr is the present system standard for transition training solely on an aircraft.

The simulator syllabus includes all maneuvers except those where visual reference with the ground is necessary. It is still desirable to do these contact maneuvers in the aircraft, as an accurate simulation of take-offs and landings is not as yet possible.

The training course as developed by PAA for accomplishing the objectives as outlined above consists of 35 hr of training in the flight simulator for a crew consisting of captain, first officer and flight engineer. The present syllabus calls for 15 hr each for the pilot and copilot at the pilot stations plus 2.5 hr each at the flight engineer station, and 30 hr for the flight engineer at his station. The flight engineer's training, of course, runs simultaneously with that of the pilots so that no extra time is required. The first training period consists of 3 hr devoted entirely to cockpit familiarization during which time each control is pointed out and its function discussed by the flight instructors. From this gradual start, the trainees work up in stages, carefully reviewing each procedure a number of times, to a crescendo at the end of the course when flight problems are flown involving airway flights, icing problems, and every conceivable emergency that can reasonably be anticipated.

By continuous repetition of simulated emergencies, it has been possible to attain a standardization of teamwork heretofore unknown within our experience in transition training. It is the consensus among the crews who have received this syllabus that their training has been more thorough than that received on any other type of aircraft which they have flown.

Transition from the simulator to the aircraft affords no problem as reflected by the low aircraft time required for complete checkout. The aircraft training is confined strictly to contact maneuvers such as landings and take-offs under such conditions as crosswinds and zero flaps. This turns out

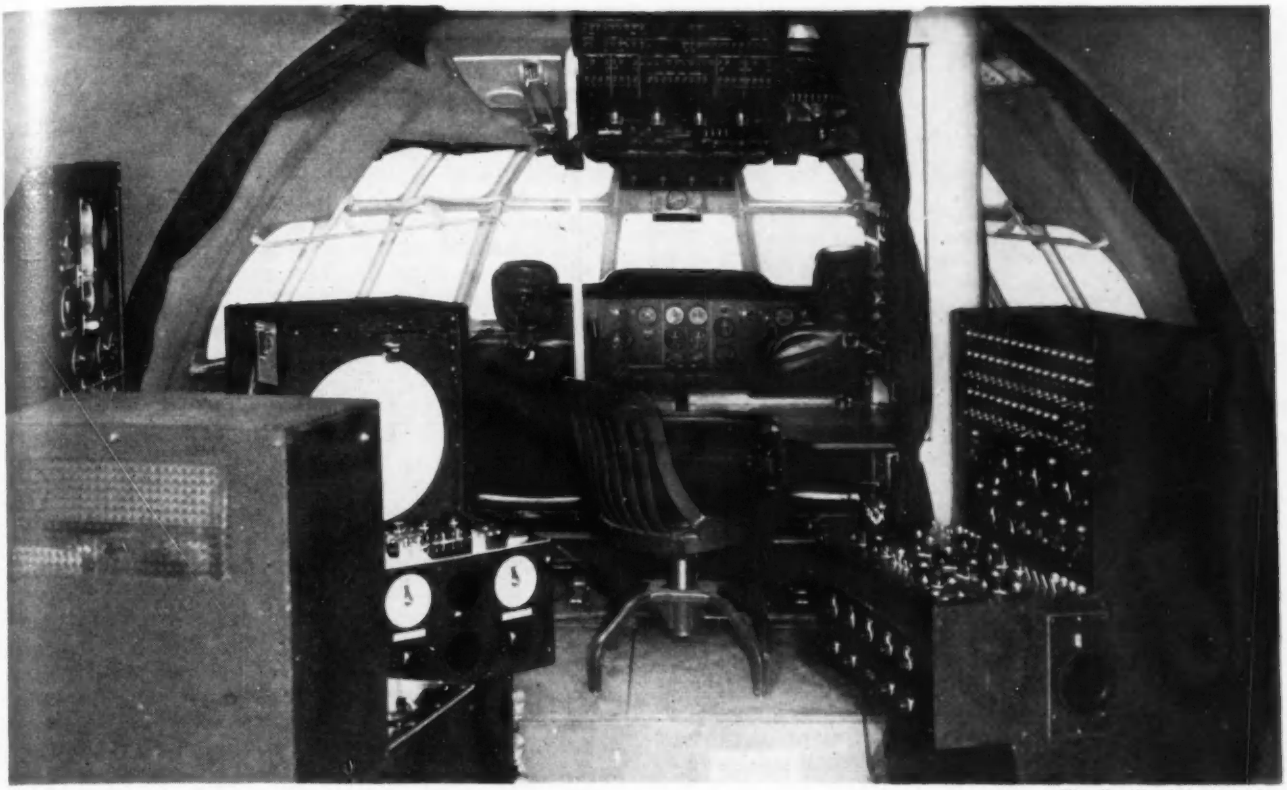

Fig. 3—Simulator interior

to be simply a demonstration, as all techniques have been carefully rehearsed in the trainer, and the repetition of maneuvers in the aircraft is seldom required.

Proficiency Training

All crew members are required to have proficiency training on the aircraft to which they are assigned at regular six-month intervals. The objects of this training are to

1. Check flight proficiency and knowledge of procedures.
2. Practice maneuvers and emergencies not normally encountered in line flying.

In an aircraft for which there is so simulator, the time required for this training averages 4 hr per captain per year. This training is normally done in two periods, each requiring 2 hr flight time. The first is an instruction or rehearsal period during which time the trainee is groomed for a check the following period. His next flight is a check during which certain requirements of the Civil Aeronautics Administration and company must be met. It is necessary sometimes to repeat a check flight for better proficiency, thereby increasing the total number of aircraft proficiency training hours required.

Since the original B-377 qualification training, we have had the opportunity to recheck 15 crews, and to date there have been no failures, nor should there be any under the new syllabus, which requires each pilot to take 6 hr training in the simulator including 1 hr at the flight engineer's station, prior to taking his semi-annual check; part of which is given in the simulator and part in the aircraft. If any weaknesses develop during the simulator training, it is possible to iron them out by additional trainer time before taking the flight check. Like the transition training, the proficiency check for the crew is divided between the simulator and the aircraft, the majority being given in the simulator and the maneuvers requiring contact with the ground given in the aircraft itself. At the present time, this requires 0.7 hr on the Stratocruiser, but a downward revision may be expected as experience is gained in this phase.

Future Objectives

To date, the trainer has been utilized full time for transition and proficiency training but this does not mean that its usefulness stops there. As soon as trainer time permits, we intend to move on to our future objectives which we believe will be obtainable with this new device.

We believe that it would be feasible to give route-proficiency checks, since most route flying is done almost entirely by use of radio aids which are, or can be, duplicated in the simulator. This, coupled with three-dimensional pictures of landing areas, leads us to believe that a competent route check from New York to New York, around the world, can be given without leaving the ground.

We also look to this trainer to provide a proving ground for new instruments and devices. This would mean a saving of substantial sums and valuable time in the development and improvement of radio aids and flight instruments.

We expect to use it also for the training of our

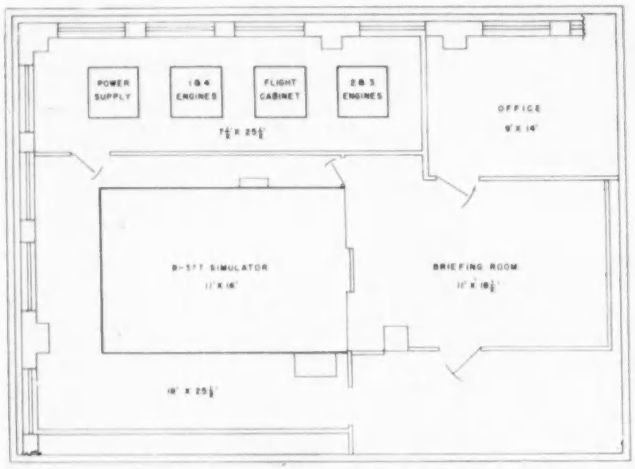

Fig. 4—Floor plan of simulator arrangement

crews in the use of new approved navigational flying aids such as the omnirange and Sperry Zero Reader. In the past, it has been necessary to do most of this type of training in the actual aircraft at great inconvenience and expense. Better procedures, instrumentation, and cockpit arrangement will be the inevitable result of additional experience in this type of trainer.

Procedures have already been changed and aircraft modifications accomplished as a result of our experience to date.

Finally, it appears possible to measure accurately the human element in air transportation. It is a foregone conclusion that there is a definite limitation to human capabilities and that any crew member's efficiency will be impaired if his attention is dissipated in too many directions at any one time. Too little regard has been given to this point by aircraft and instrument designers as evidenced by the complexities apparent in aircraft instruments, radio aids, and communication facilities. The sound approach to this problem would seem to be an accurate measuring of the limiting point of dissipated attention and the designing of aircraft to provide sufficient margin below it.

As an extra dividend, the natural byproduct of this type of training is the conditioning of crews to the eventual problem of blind approaches and landings since everything is done necessarily on instruments."

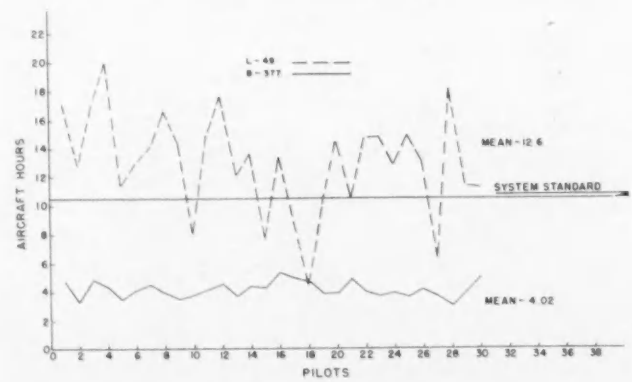

Fig. 5—Flight hours required for checkout on aircraft

Table 1 illustrates a few of the common mistakes made on the simulator and the results. Certainly no training on actual aircraft can be allowed to go to these extremes. (Of course, it's not only PAA flight crews but also the crews of other operators whom PAA has trained who make mistakes.) These errors can be classified as human failures.

A PAA captain summed up the advantages of this type of training when he stated, "I have flown for PAA 14 years and have checked out in 10 different types of equipment, but this is the first time I have ever felt at home upon entering the cockpit of a new aircraft."

Limitations

The shortcomings of the simulator have been classified as lack of physical acceleration effects and yaw, lack of visual reference, and the psychological lack of hazard—all of which are relatively unimportant, when considering the results being attained.

Despite a very accurate control feel and instrument response to control movements, there is a complete lack of "g" forces, acceleration and deceleration forces, and yaw, which the pilot normally feels and reacts to when flying an actual airplane on instruments. Being able to feel these various forces is of considerable assistance in actual instrument flying, but flying the simulator without these sensual indications is quite difficult, requiring the utmost vigilance on the part of trainees who are able to divert their attention from the flight control instruments but briefly for fear of missing an important indication of say an engine failure.

Due to lack of visual reference, the trainee cannot actually see a landing runway and plan his own landing approach. Approaches must be made with a good deal of imagination, requiring assistance from the flight instructor, who also must use some imagination, advising trainees when abeam runway on downwind leg and if too high or low on final approach. With these methods, however, it has been possible to instill in trainees' minds the desired airspeeds, approximate power settings, and landing patterns for normal three-engine, two-engine, zero-flap, and low-ceiling and low-visibility landings. Taxiing the simulator without visual reference is not very realistic despite accurate instrument reaction when steering with the nose wheel. This offers no problem however, for taxiing the aircraft actually is a very simple maneuver similar to that of other aircraft with steerable nose wheels. The proof of the pudding is the demonstration of these maneuvers in the aircraft with no further instructions.

The feeling of danger while accomplishing a marginal maneuver is almost never present in a ground-bound training device. In the simulator, however, this psychological aspect is present to some degree due to the overall realism of the cockpit surroundings and performance responses.

In general, it is felt that the above effects, while classified as limitations, in no way deter from the overall advantages of training in the simulator.

Within the past 12 months, the unit has operated

for 2750 hr of training. This is equivalent to 3300 hr of operating time due to the unit's running all day between classes and at various other times for demonstrations to other airline personnel and for maintenance or calibration work. During this period, only five hours of training have been canceled due to breakdowns requiring maintenance: one hour due to a cold solder joint on a servo, one hour due to a blown fuse on the power supply, and three hours due to a failed inverter in the power cabinet.

PAA employs two maintenance men in its training section who work shift hours, so that there is always one available during the training day. These men are charged with the maintenance, overhaul, and modification of the B-377 simulator plus three Link trainers equipped with Curtiss-Wright electronic radio aids units. There are no fast moving parts in the simulator or other units which receive excessive wear. Therefore the maintenance time is utilized mostly in a constant round of cleaning, inspection, tube testing, and adjustment. The greater part of this work can be accomplished during normal operation of the unit.

Maintenancewise, the B-377 simulator has not presented and is not expected to present a major problem.

The utilization on the simulator currently averages 12 hr per day for seven days a week. At times, the utilization has reached 16 hr per day for a period of a week.

Economics

The most intriguing feature of the flight simulator is its ability to save money.

Fig. 6 illustrates the annual savings possible with the B-377 aircraft. From the two curves for "initial & recurring training" and "recurring training" on a 10-year amortization basis, it will be noted that using the simulator brings a saving with a fleet of aircraft greater than two.

The curve representing "recurring training" on a 5-year amortization basis indicates an annual saving on a fleet of aircraft larger than six.

An extreme case, the curve labeled "L-49 Recurring Training," is based on an initial cost of $275,000 for the simulator and a 5-year amortization period. This shows that for a fleet of aircraft over ten, an annual saving is possible for recurring training alone. [Assumptions made in calculating for these curves are explained in the complete paper.]

On similar curves for the CV-240 aircraft, the cross-over points for both "initial and recurring training" and "recurring training" on a 10-year basis, appear for fleets of more than four aircraft.

The 5-year curve for "recurring training" only shows a saving for fleets of nine aircraft or more.

The two factors which have the greatest effect on savings, which should be noted by both the manufacturer of the simulator and its operators, are (1) the initial cost of the trainer and (2) the period over which these costs are depreciated.

The manufacturer must not include in the design of the simulator those characteristics which duplicate the ultimate performance of the aircraft in all its details, to the detriment of the initial cost. A balance between design and cost must be determined to give a reasonably accurate simulation of the aircraft at a reasonable price. PAA feels that this balance of cost with performance duplication has been achieved in the simulator the company is presently using.

Likewise the operator must take a practical view of amortizing his costs to receive the full benefits of the simulator, and must not force upon the manufacturer design detail from which marginal training benefits will accrue.

Paper on which this abridgement is based is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members; 50¢ to nonmembers.

Table 1—Fatal or Near-Fatal Mistakes

Situation	Error	Result
Fire No. 2 power section	Engine feathered and cowls opened—fire progressed into Zone 2—not noticed. While performing after feathering check, throttle pulled back on No. 1 by mistake.	Error discovered
Horizon failure following takeoff.	Slow transition to turn and bank and airspeed indications.	Crash.
With 3200 lb fuel in outboard tanks, and 1800 lb in inboards, No. 1 engine failed.	Engineer failed to crossfeed and No. 2 engine failed.	Error corrected in time.
400-ft ceiling and 1-mile visibility.	Climb-out turn made too steeply and slowly.	Crash.
No. 2 engine failure during airwork period.	Engineer pulled back mixture on No. 3.	Error discovered after several minutes of "sensing something wrong."
Transition from range to Oakland ILS.	Trainee descended 1500 ft below altitude prescribed between Oakland and Newark.	Crash.
Pull-up on three engines.	Tried using climb power for pull-up.	Crash.

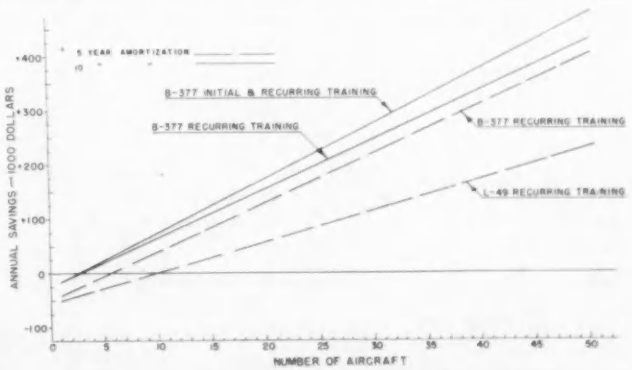

Fig. 6—Annual savings versus number of B-377 aircraft

Jet Engine

Described here in brief is the method used by North American Aviation to measure the thrust output of turbojet engines in flight. In fact, it has been used to obtain these data at true air speeds in excess of 600 mph and at altitudes extending from sea level to over 40,000 ft.

Included in the original paper is the flow equation for determining the net thrust, along with the names of references that present the derivation of this equation.

The paper also discusses some of the installation factors affecting output; namely, inlet duct design, cooling air ejector design, bleed air requirements, and tailpipe temperature control.

PERFORMANCE of turbojet engines can now be measured in actual flight by means of instrumentation that is neither extensive nor unreasonably elaborate.

Basically, the technique consists of measuring the flow conditions in the exhaust stream with an exhaust gas survey rake, such as shown in Fig. 1.

This rake is placed in the tailpipe nozzle, as shown in Fig. 2, to give readings of gas pressures and temperatures, from which the thrust output of the engine can be calculated.

Description of Procedure

In order to calculate thrust by this method two components of thrust must be evaluated: the gross thrust output and the ram drag. The difference between these two components equals the net change in the momentum of the engine induction air as it passes through the airplane. It is the resultant force that is utilized to overcome the aerodynamic drag forces acting on the airplane, since all factors that influence powerplant output are inherently included in the net thrust term.

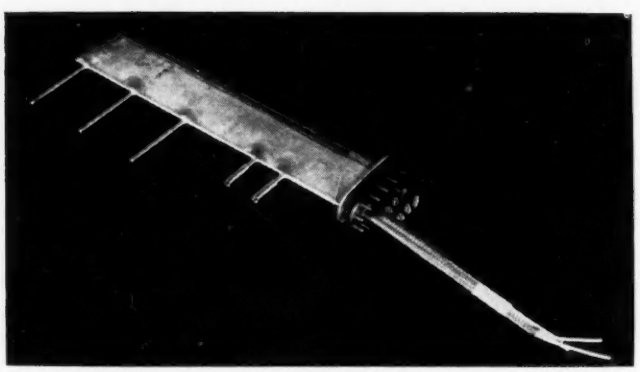

Fig. 1—Exhaust gas survey rake with three total pressure tubes and two thermocouples

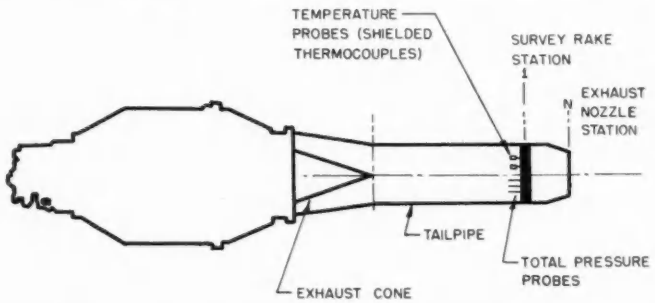

Fig. 2—Turbojet engine with exhaust gas survey rake in place

Thus, the net thrust is equal to the gross thrust minus the ram drag, which is the component of gross thrust required to accelerate the inlet air to airplane velocity.

Four quantities must be known in order to evaluate the gross thrust:

1. Stagnation or total pressure of the gas.
2. Stagnation temperature of the gas.
3. Static pressure of the gas.
4. Area of the nozzle.

Values for Nos. 1 and 2 are obtained by sampling the exhaust gases with the survey rake in the tailpipe (Fig. 2). Three total pressure tubes and two thermocouples are located so as to measure the mean average stagnation pressure and temperature of the exhaust gases immediately up stream from the nozzle. The thermocouples used in this assembly are composed of chromel-alumel leads and are shielded to pick up total temperature. The temperatures, which range up to about 1500 F in unaugmented flow, are sensed by a potentiometer and are recorded by an automatic flight recorder.

The total pressures are transmitted directly from the pickup leads to manifold pressure gages, where they are recorded on film. Total pressures are measured in this manner with the required high degree of accuracy, since a misalignment of 10 deg can exist between the pressure tube and the direction of flow without inducing appreciable errors in total head measurement.

Item 3, the static pressure at the tailpipe exit, is set equal to the atmospheric pressure. Item 4, the nozzle area, is measured directly.

With all four variables known, the gross thrust at the nozzle can be calculated.

While the instrumentation just described is fully adequate to determine the thrust of an unaugmented turbojet engine, the extreme temperatures encountered with afterburning prohibit their use when an afterburner is in operation except to

Thrust — Measured in Flight

BASED ON PAPER* BY

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* Paper, "Ground and Flight Evaluation of the Performance of Jet Powerplant Installations and Some Installation Factors Affecting Output," was presented at the SAE Annual Meeting, Detroit, Jan. 11, 1950

measure gas-flow conditions up stream from the afterburner. With these installations, a special water-cooled or aircooled survey rake is required.

At present, only the total pressure is determined by this method, since a completely satisfactory means of recording these temperatures has not been developed for flight test purposes. However, temperatures at the exhaust nozzle may be calculated with reasonable accuracy from gas conditions measured up stream from the afterburner.

The other component of thrust that must be measured is the ram drag of the engine induction air, which is equal to the gross thrust times the ratio of the airplane velocity to the exhaust gas velocity, if it is assumed that the mass of the induction air is equal to the mass of the exhaust gases. Actually, fuel is added to the flow, approximately one part in sixty, but this generally balances the air bled from the compressor for cabin ventilation, cooling, and compressor leakage. For engines that are thrust augmented by after burning or water-alcohol injection, allowance must be made for the change in mass flow through the engine.

Calibration Factor

Certain inaccuracies exist in the thrust values as calculated according to this method because of the assumptions made in deriving the flow equations, but these errors can be calibrated out by applying suitable nozzle coefficients (the ratio of actual thrust to calculated thrust), which are determined during static ground tests.

More specifically, the factors of viscosity, turbulence, and discrepancies in pressure integration are not accounted for by the fundamental relation. Thus, the calibration factor, which accounts for these inaccuracies, is obtained under conditions that permit the direct measurement of true thrust and the measurement of variables used in determining the ideal calculated thrust. The factor thus obtained is plotted as a function of the ratio of atmospheric pressure to exhaust gas total pressure, as shown in Fig. 3.

The calibration factors can be quite accurately determined by wind-tunnel or flying test-stand tests, but the method most practical for the airframe manufacturer consists of obtaining static thrust measurements on the ground, where the output of a given installation is measured through a system of spring scales, strain gages, thrust balancing pistons, or other mechanical means. An overall probable error in net thrust determination of 1½% over the normal operating range of the airplane is believed to be reasonable for this method. Of course, an individual calibration factor must be

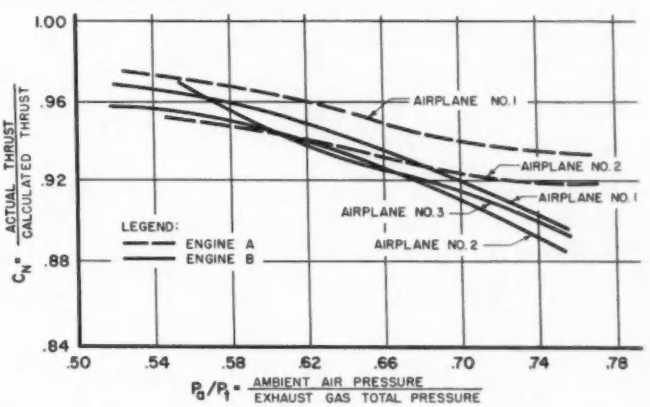


Fig. 3—Typical thrust calibration factors for turbojet engines (installed)

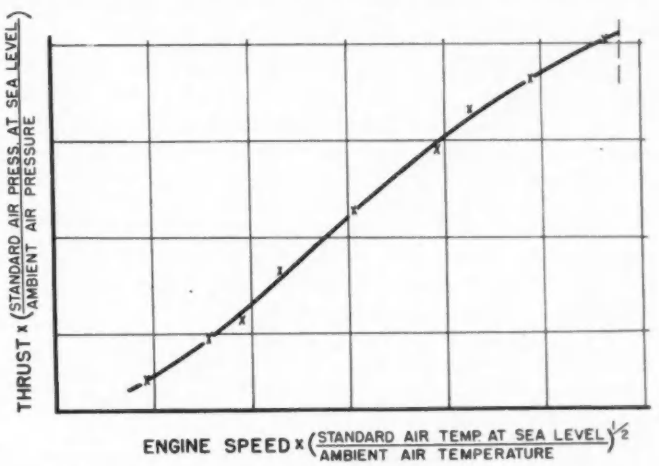

$\text{THRUST} \times \left(\frac{\text{STANDARD AIR PRESS. AT SEA LEVEL}}{\text{AMBIENT AIR PRESSURE}}\right)$
$\text{ENGINE SPEED} \times \left(\frac{\text{STANDARD AIR TEMP AT SEA LEVEL}}{\text{AMBIENT AIR TEMPERATURE}}\right)^{1/2}$

Fig. 4—Method of presenting engine performance data obtained during static ground tests

established for each test powerplant installation, since engines of the same series give varying thrust performance under identical operating conditions.

It is usually desirable to correct the observed thrust values to standard conditions of air pressure and temperature, and also to some standard engine rpm and airplane speed, so that engine and airplane performances can be compared.

The reduction of engine performance data obtained during static ground tests is easily accomplished. The actual values of thrust obtained are simply corrected by the ratio of standard atmospheric pressure at sea level to the test ambient total pressure, and the observed engine speed is corrected by the square root of the ratio of standard air temperature at sea level to ambient total temperature at the test stand. Then corrected thrust can be plotted against corrected engine rpm, as shown in Fig. 4.

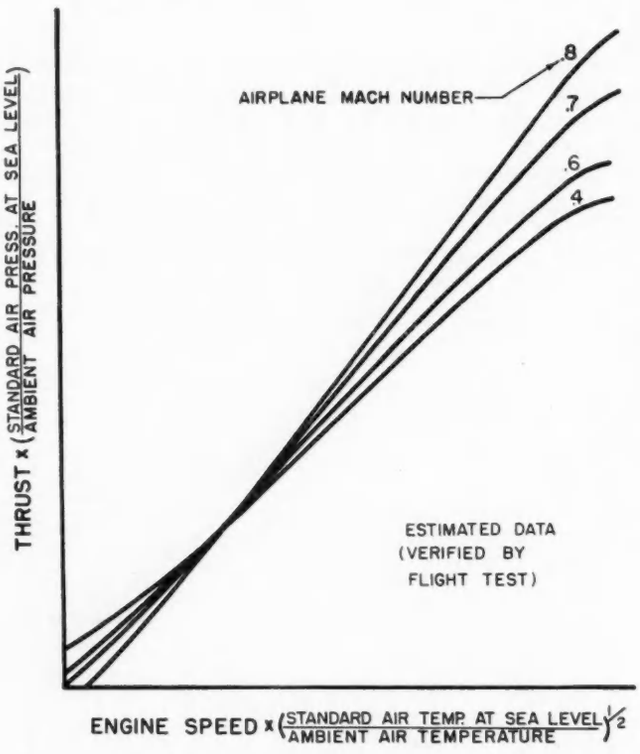


Fig. 5—Engine performance data used in reduction of observed flight thrust data

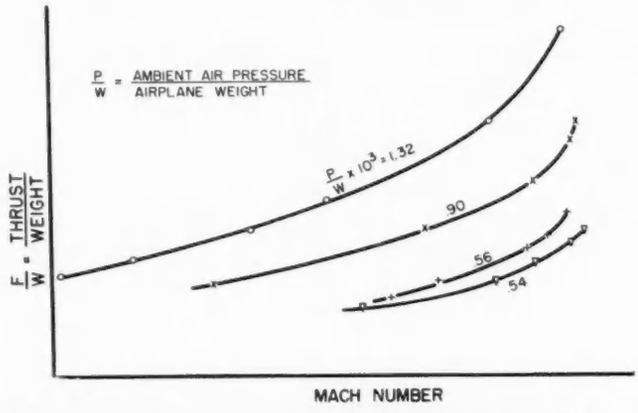


Fig. 6—Dimensionless speed-power data from flight test results for use in reduction of data to standard conditions

Values of engine thrust and rpm can be taken directly from the curve for standard sea-level conditions and, by using an appropriate pressure and temperature ratio, engine thrust and rpm can also be obtained for the curve for nonstandard atmospheric conditions. Inlet duct losses, when not of a negligible magnitude, are taken into account by correcting the thrust values to compressor inlet pressure.

A slightly different method is used for reducing flight data to standard conditions. Since the changes to be made in engine rpm and airplane speed are known, the reduction may be made with the aid of graphs of estimated engine performance, which are used to obtain an increment of thrust corresponding to the change between observed and standard conditions. Thus, the correction can be made by adding the increment of thrust to the actual observed thrust value.

Again the thrust values are corrected by the ratio of standard atmospheric pressure at sea level to the ambient total pressure at the test altitude, and the observed engine speed is corrected by the square root of the ratio of standard air temperature at sea level to ambient total temperature at the test altitude. When this is done for all speeds, the estimated engine data assume the form shown in Fig. 5.

The estimated engine performance data contain all corrections for installation losses, such as inlet ducting tailpipe configuration and compressor bleed. The data reduction process utilizing the estimated data thus inherently allows for all changes in installation effects. By obtaining sufficient flight data the curves shown in Fig. 5 used for data reduction can be based entirely on flight tests instead of being estimated, although excellent correlation between the estimated and the actual data has been obtained for the entire operating range of the engine.

The reduction of airplane performance to standard atmospheric conditions is closely connected with engine reduction methods, since airplane performance depends on both the power required and the power available. The power required is a function of drag, which in turn is a function of altitude, Mach number, and weight. In airplane reduction these variables are appropriately included by the nondimensional plots shown in Fig. 6 for level flight performance.

Standard performance is obtained by entering the plots at standard values of temperature, pressure, thrust, gross weight, and then reading the corresponding airplane Mach number. For a single level flight point, when complete speed-power data are not available, correction to standard conditions is obtained by constructing curves similar to those shown in Fig. 6 from estimated data. The estimated graph is used in identical manner and an increment of velocity is obtained when going from observed to standard conditions. This increment is then used for correcting the single flight point.

Climb data are reduced at constant Mach number, so that drag changes due to Mach number are avoided in the reduction process.

This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.

British Views On JET ENGINE DESIGN

EXCERPTS FROM COMMENTS* BY

G. Geoffrey Smith

Directing Editor of Flight and Technical Publications of Iliffe & Sons, Ltd.

AIRCRAFT gas turbine development in both America and England is making considerable progress, although the aproach to component design varies somewhat. This emerges from a survey of the thinking in Britain on items such as engine types, fuel consumption, compressor types, ignition systems, and thrust augmentation.

As in the United States, major emphasis in England is on new type axial flow turbojets for military aircraft. We must congratulate you on the Allison XT38 unit, which is exceptionally slim, and also on the North American F-86 swept-wing fighter with the General Electric TG-180 axial unit, of which we have good reports. We also are gratified at the healthy progress in Canada with the Avro (Canada) Chinook and Orenda turbojets.

In Britain, attention is focussed on the Rolls-Royce Avon and Armstrong Siddeley (originally Metropolitan-Vickers) Sapphire. These are at present our most powerful types and may be expected to figure largely in our jet bomber program.

It has always been known that small frontal area was desirable; but as operational speeds are raised, this factor becomes critically important.

In our Meteor twin-jet fighters, Rolls-Royce Avons of 6500 lb thrust give a rate of climb of 10,000 fpm. Using water-methanol injection and afterburning, we can claim to be on the threshold of achieving 10,000 lb thrust from a single unit. By combining a shot in the arm and a kick in the pants, you can almost double the thrust.

The centrifugal type has not been abandoned for military craft. The deHavilland Ghost, for example, is being actively developed in the deHavilland Venom high-altitude fighter. And there is the Rolls-Royce Tay, delivering 6250 lb thrust, which is over 400 lb lighter than its axial brother Avon.

British faith in relatively low-powered turboprops for civil use—typified by Armstrong Siddeley Mamba and Rolls-Royce Dart—is unshaken. We are pleased with the result of the icing trials of the Dart and the performance of this unit in the Vickers Viscount, as adopted by British European Airways.

For our largest civil aircraft, the Bristol Brabazon landplane and the Saunders-Roe Princess flying boat, we are committed to the Bristol coupled multi-stage Proteus, which has unfortunately been delayed by improvements now being introduced.

It is interesting to note that in America you are working on somewhat similar lines. I refer to the installation of Allison XT-40 units in the Convair XP5Y1 long-range flying boat.

The first turboprop likely to be introduced in regular military use is the larger Armstrong Siddeley Python, now in production for carrier-borne strike aircraft. Valuable experience also is being accumulated with the coupled Mamba in new anti-submarine aircraft. For this duty the coupled turboprop, offering cruising economy and high maximum power for closing on the target, appears ideally suited.

We expect a progressively stronger challenge from America in the turboprop field.

Fuel Consumption

Present fuel consumption rate of turbojets is admittedly too high, which narrows the field of utilization. But this need not be a permanent handicap.

Continued research into combustion problems has led to steady reduction of rate. For instance, by improving combustion technique and auxiliaries alone, the Joseph Lucas laboratories has reduced fuel consumption rate by 9% in three years.

It is confidently expected that current investigations into spray characteristics, the size of droplets, and distribution of atomized sprays—as well as aerodynamic, mechanical, and metallurgical advances improving thermal efficiency—will effect further benefits. This progress will be supplemented by many here-and-there improvements, dictated by constant research and experiment with individual components, so that the specific rate of consumption may be reduced by a further 15 to 20% in the next three years.

We are aiming for a figure of 0.8 lb per lb thrust per hr at sea level static, and 1.1 lb per lb thrust per

* Comments were made at SAE National Aeronautic Meeting, New York, April 18, 1950.

hr at 600 mph in the stratosphere.

Although important, the specific consumption of the bare power unit is not necessarily the best indication of its suitability for a particular duty. The turbine powerplant, which can furnish cabin pressurization and deicing, and incidentally save 500 to 600 lb weight of independent auxiliaries, shows to an advantage in this respect over the piston engine. The main compressor of the turbine provides automatic auxiliary services at an appreciable saving in weight.

For a particular aircraft, it would be more informative to quote the rate of fuel consumption "for all purposes," as is the practice in shipping circles. The day has gone in high-altitude turbine-propelled aircraft to quote bare engine fuel consumption. We must recognize what is saved in the matter of auxiliaries and thus offset differences in fuel consumption. It must be confessed in this regard that axial flow compressors are more "touchy" in being bled for these services than is the centrifugal type.

Component efficiency of the axial type is higher at say 88%. A higher compression ratio can be used to make possible a lower specific rate of fuel consumption (say 12 to 15% lower). Also its relatively smaller diameter permits tighter installation and reduced frontal area—an all-important consideration at high Mach numbers which may dominate the choice.

The contrifugal compressor is cheaper than the axial type to develop, to produce, and to maintain. It certainly is of more robust construction and less vulnerable to foreign bodies or icing. Its efficiency can be put at 79 or 80%.

Although great effort is being lavished on the axial type, it must be acknowledged that the civil airliners now flying and doing real work—the deHavilland Comet, Avro Jetliner, and Vickers Viscount—are fitted with centrifugal compressor units.

High Energy Ignition System

Typical of our detailed research into particular problems affecting turbine operation is the high energy ignition system developed by the Royal Aircraft Establishment.

This has enabled us to dispense with the familiar torch igniter and its auxiliary fuel spray; the electric discharges this system produces at the rate of about one per second are of such high energy and short duration that each can by itself create ignitable conditions in the combustion chamber.

Each discharge can vaporize a sufficient quantity of the main fuel spray and then ignite a sufficient volume of the resulting mixture to produce a general "light-up" in the chamber.

It was found that electrode erosion of the orthodox high-voltage igniter plug was too rapid. This led to use of a surface discharge type plug with a large electrode area. This consists of two circular electrodes of heat-resisting steel, separated by an annular gap of 0.02 in., in which mica is tightly compressed and made flush with the electrode surfaces. A thin carbon layer is deposited on the mica surface and the plug is positioned in the combustion chamber so as to maintain this deposit during normal operation.

In the ignition system an induction coil, operated by a vibrator from a 24-v d-c supply, repeatedly charges a condenser through a sealed spark gap until the condenser voltage increases to about 2 kv. The condenser then discharges through a 2-kv sealed spark gap, an inductance, and the surface discharge plug—all in series. Discharge duration is of the order of 50 microseconds and the peak current is about 1500 amp. Total weight of the equipment, including a screened plug lead, is about 10 lb.

The system has successfully ignited aircraft turbine combustion chambers in the test house over a range of limiting combustion conditions—from high pressures equivalent to those at high flying speed at low altitudes, to low pressures encountered at high altitudes. In actual flight, successful relights have been obtained on several turbine units at altitudes up to about 35,000 ft. This system is not yet in general service use.

You seem to be somewhat ahead of us in application of afterburning to standard aircraft. In Britain we are developing afterburning (or reheat as we are urged to call it) as a temporary power-boost system for fighters and bombers, as demonstrated at the last Farnborough Display. With increased temperature, it gives greater percentage efficiency—a theoretical 34% at 1500 K.

For civil aircraft, particularly as take-off boost, we incline towards water-methanol coolant for the compressor; afterburning equipment is calculated to impose a penalty of 2 to 3% on the cruise consumption. We estimate that a 10 to 12% maximum benefit can be gained from water-methanol injection. If more is obtained, it is regarded as an indication that the characteristics of the compressor and turbine are poorly matched.

Both water-methanol and liquid rocket motors have been developed to assist the take-off of the deHavilland Comet jet liner when fully loaded, from tropical or high-altitude runways. During various tests throughout the winter, the record-breaking Comet has been successfully flown 5¾ hr at a stretch with standard tankage. The next specimen will have more tankage in the wings and a bogey undercarriage.

It is estimated that, with improvements in the Ghost turbines, another 5% reduction on published figures of specific fuel consumption will be achieved. Present tests have been made at 35,000 to 40,000 ft; but the Comet will go to 45,000.

Cooperation Holds Benefits

Enormous benefits are to be obtained by technical cooperation between our countries. It existed even before Pearl Harbor, when our first Whittle engine was flown to the General Electric Co. in the United States. The Rolls-Royce and Pratt and Whitney arrangement is another excellent example of mutual aid.

As turbine power units become more complicated, the incubation period between initial inception and delivery for service tends to lengthen. Continued technical liaison can materially reduce this critical period, and have the combined effect of strengthening our positions in the van of engineering progress and provide added security in a troubled world.

Standardization of all minor parts should be pursued so long as it is not permitted to impede design. But we should be on our guard against any attempt to standardize ideas.

Texaco Combustion Process Gives Knock-Free Operation

EXCERPTS FROM PAPER* BY

E. M. Barber, The Texas Co. **Blake Reynolds, and** Texaco Development Corp. **W. T. Tierney** The Texas Co.

* Paper "The Elimination of Combustion Knock—Texaco Combustion Process," was presented at SAE Summer Meeting, French Lick, Ind., June 5, 1950. This paper will be printed in full in SAE Quarterly Transaction.

THE Texaco Combustion Process[1] (TCP) is a combustion method, combining fuel injection and spark ignition, which is so controlled that knock does not occur, regardless of the fuel's octane number or the engine's compression ratio or supercharge. A predictive glance reveals that TCP type engines can yield a minimum of 30% more miles per gallon and 30% more gallons per barrel.

TCP is relatively insensitive to fuel volatility and it readily handles fuels of a broad boiling range, such as 100 to 600 F. The features of TCP that prevent knock also allow a wide range of mixture strengths to be burned. This results in high efficiency at part load and in load control by mixture strength. TCP's elimination of knock, its toleration of wide boiling range fuels, and its ability to burn lean mixtures make it a basis for substantial improvements in the utilization of internal-combustion engines and their associated liquid fuels to attain greater power per unit of engine size, more miles per gallen of fuel, and more gallons of fuel per barrel of crude petroleum.

Gains with TCP

To realize these benefits, engines must be built to exploit one or more of the favorable features of TCP. This resolves itself into an exploitation of the following features:

(1) As the result of TCP's knock elimination, compression ratio may be increased without regard for the octane number of the fuel.

(2) As the result of TCP's knock elimination, supercharge may be employed, in combination with high compression ratio if that is desired, without regard for the octane number of the fuel. This may be done, for example, with a small engine to reduce losses at the load of average use; with a larger engine to obtain torque variation without a complicated multi-speed transmission, or simply to obtain high power from a given size of engine.

(3) TCP's ability to burn lean mixtures will result in a favorable part load fuel economy in almost any TCP engine application.

(4) TCP's ability to control load by mixture strength, without air throttling, makes it attractive for two-cycle engines which have many desirable characteristics when the mixture strength method of load control can be employed.

(5) A TCP engine can utilize fuels having no octane number specification and a broad boiling range. The yield of such fuel from most crude oils can be substantially greater than the combined yields of motor gasoline, aviation gasoline, and diesel fuel meeting current octane number, cetane number and volatility specifications.

Theory of the Texaco Combustion Process

The sequence of events that leads to the occurrence of knock in a conventional Otto cycle engine, that is, an engine operating with spark ignition and a premixed charge, is a convenient point of departure to describe the concept and theory of the Texaco Combustion Process.

Fig. 1 shows a typical plan view of the combustion chamber of an Otto cycle engine, with the piston near top center and the combustion in progress. A flame front has been established at the spark plug and it is burning into the combustible mixture, compressing ahead of it the unburned portion of the combustible air-fuel vapor mixture. The air-fuel vapor mixture that will be burned last, the "end gas," will be compressed to the greatest degree. Under the resultant "end gas" temperatures and pressures oxidation reactions occur which may lead

[1] U. S. Patent 2,484,009, October 11, 1949, Internal Combustion Engine and Method of Operating Same, Everett M. Barber, Assignor to the Texas Company, New York, New York, a Corporation of Delaware.

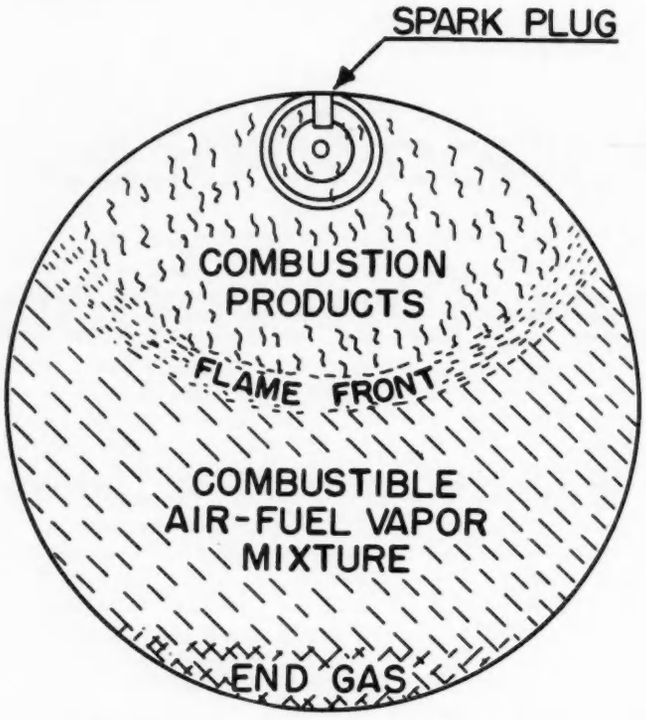
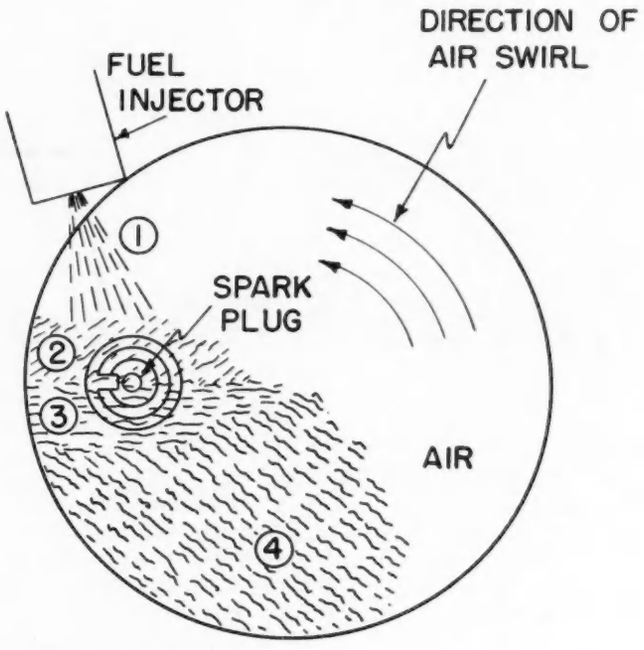


Fig. 1—How combustion progresses in an Otto cycle engine



1-FUEL SPRAY
2-COMBUSTIBLE AIR-FUEL MIXTURE
3-FLAME FRONT
4-COMBUSTION PRODUCTS

Fig. 2—Diagram of the Texaco Combustion Process in which swirl is imparted to the air. (1) is the fuel spray; (2) the combustible air-fuel mixture, (3) flame front, and (4) combustion products

to spontaneous ignition of the end gas. This spontaneous ignition has been identified as knock.

Under engine conditions of end gas pressure and temperature, spontaneous ignition, or knock, almost invariably would occur if the end gas reactions were allowed sufficient time. However, the end gas may be consumed by the normal progress of the flame front before the end gas reactions reach the stage of spontaneous ignition and, in this event, no knock will occur. Thus, the occurence or non-occurrence of knock may be likened to a race between the spontaneous ignition reaction in the end gas and the normal progress of the flame front.

In the study of spontaneous ignition reactions, three quantities are of major importance in characterizing the reaction of any given air-fuel vapor mixture. These are the pressure and temperature and the ignition delay, the latter being the residence time of the mixture at the conditions of pressure and temperature before spontaneous ignition occurs. For a given mixture, the ignition delay time decreases exponentially as the pressure or temperature is increased.

It is customary to think of pressure and temperature as the cause, and of the residence time, prior to spontaneous ignition, as the effect. For the present purpose, however, it is convenient to reverse this thinking to consider residence time as the cause and the pressures and temperatures that will produce spontaneous ignition within that residence time as the effect.

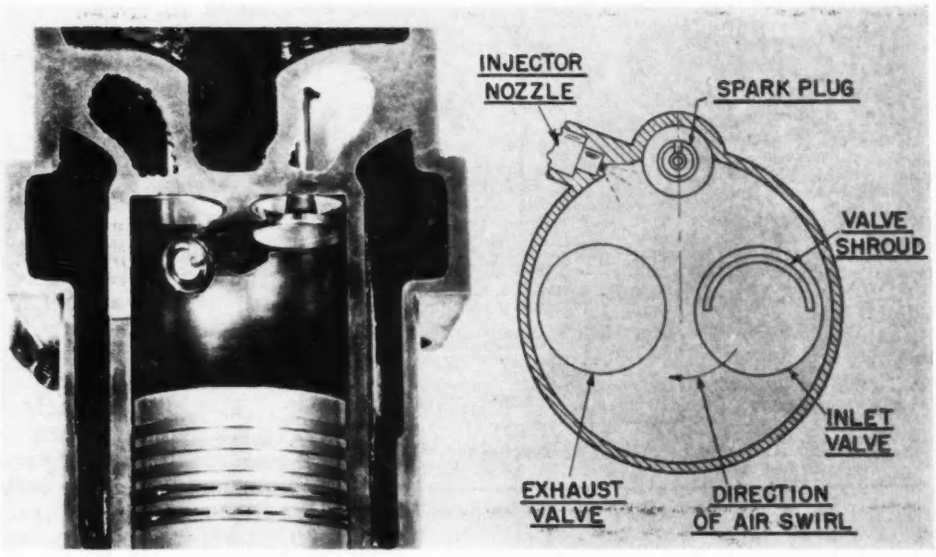
With this reversal, we have a basis for understanding the concept of the Texaco Combustion Process: to make the residence time of combustible mixture so brief that spontaneous ignition and knock will not occur at engine pressures and temperatures.

Fig. 2 is a schematic illustration of the way in which the Texaco Combustion Process is carried out to eliminate combustion knock by reducing the residence time of combustible mixture at combustion chamber temperatures and pressures. Referring to

Table 1—Texaco Combustion Process Range of Knock-Free Operation

Compression Ratio	6 to 12 to 1	
Manifold Pressure	10 to 120 in. of hg absolute	
Jacket Temperature	212 to 375 F	
Intake Air Temperature	90 to 400 F	
Speed	200 to 4400 rpm	
Load	Idle to Full Load at Any Speed	
Flexibility	Acceleration and Rapid Load Change at Any Condition	
IMEP	20 to Greater than 400 psi	
Fuels	Iso-pentane	Triptane
	Alcohol	Iso-octane
	Benzene	N-Heptane
	Kerosene	Cetane
	Diesel Fuel	α-Methyl-Naphthalene (and others)
	Tractor Fuel	

Fig. 3—General arrangement of the experimental apparatus for the Texaco Combustion Process



the figure, the air in the combustion chamber is caused to have a swirling motion, and fuel is introduced into the combustion chamber across the swirling air and in its downstream direction. A spark plug is located a short distance from the fuel nozzle, downstream from the nozzle.

The first element of fuel that is injected mixes with the air as it travels toward the spark plug. The resultant mixture is ignited substantially as soon as it reaches the spark plug. The remainder of the fuel is injected continuously into the swirling air. During this continuing injection a flame front is established; fresh combustible mixture is formed continuously and fed into the flame front, and combustion products are carried away from the flame front.

It will be noted from Fig. 2 that, in addition to reducing the residence time of combustible mixture at engine pressures and temperatures, TCP makes it possible to burn very lean overall air-fuel mixtures by terminating the injection before all of the swirling air has been been mixed with fuel. It follows that high part load efficiencies can be obtained and that the engine power can be controlled by variation of fuel quantity without air throttling.

TCP Apparatus and Characteristics

Experimental apparatus used for one of the early trials of the Texaco Combustion Process is illustrated by the photograph of a sectioned cylinder and by the plan view of the cylinder, shown in Fig. 3. The cylinder shown is of the four cycle poppet valve type, 3¼-in. bore by 4½-in. stroke. Air swirl is induced by the shrouded valve and the spark plug is located approximately 30 deg of arc downstream in the air swirl from the injector position.

The cylinder shown was used in the earliest TCP experiments. A variety of cylinders of the same bore and stroke have been used in most of the development work. Other cylinders both of the two and four cycle variety and ranging up to 6-in. bore by 6-in. stroke also have been used. All cases have involved the following common features: a method for creating air swirl, the relative location of the injector and spark plug, and a combustion chamber shape that is esentially a figure of revolution.

With the engine arranged generally as shown by Fig. 3, the resultant operation is knock free, regardless of the octane and cetane numbers of the fuel and the operation also is relatively insensitive to the volatility of the fuel. This freedom from the occurrence of knock, regardless of the octane or cetane number of the fuel, is illustrated by Fig. 4, which shows curves of imep versus fuel-air ratio for five fuels which represent approximately the known ex-

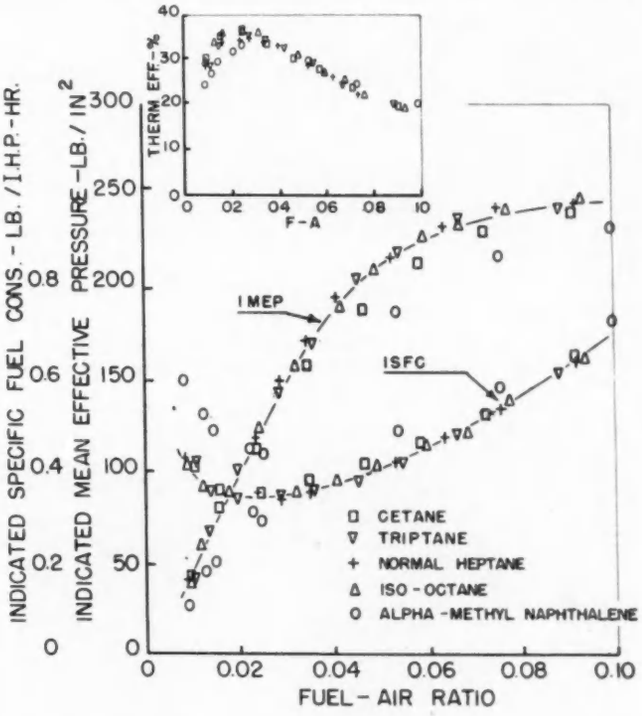


Fig. 4—These data show how the Texaco Combustion Process is free of knock, regardless of the type of fuel burned

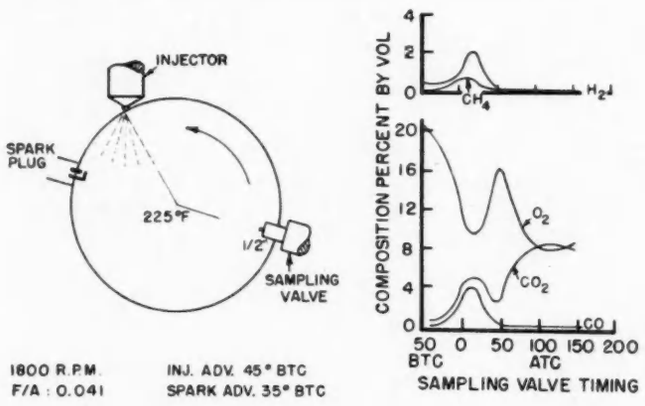


Fig. 5—Set-up for taking patch burning samples and resultant data

tremes of octane and cetane numbers.

All data illustrated in Fig. 4, were obtained during a single continuous operating period of the engine during which no adjustments were made except to change fuel quantity as required to develop the curves and to change from fuel to fuel. The engine operation was at 1800 rpm, 10 compression ratio, 60 in. of hg absolute manifold pressure.

As the engine was changed from fuel to fuel there was no noticeable or measurable difference, except the slight power changes attributable to changes in the heating value of the fuels. Fig. 4 also illustrates the ability to burn lean mixtures and to control load by mixture ratio only.

It has been of additional interest to investigate the operation of TCP engines over a wide range of operating conditions to obtain assurance that the knock elimination persisted to extremes of the conditions that ordinarily are conducive to knock, and to investigate the flexibility and general operability of a TCP engine. As a point of departure for these extremes, the commonest operation has been in the range of 1800 rpm, at 10 compression ratio, 90 F intake air temperature, 212 F jacket temperature, 30 to 60 in. of hg absolute manifold pressure on a 24 octane number fuel having a boiling range from 100 to 600 F.

Some of the more important extremes of operating conditions are listed in Table 1. Throughout these ranges of operating conditions knock-free operation has been obtained. Furthermore, during accelerations, abrupt load changes, and so forth, it is possible to operate without spark or injector adjustments. The general impression is that of a very flexible operation.

In a TCP engine, if the injection of fuel is terminated before a complete air swirl has occurred, only a portion or "patch" of the air will have been impregnated with fuel vapor. The fuel-air ratio of the patch will depend on the mass rate of air swirl and on the mass rate of fuel injection. The patch fuel-air ratio will be greater than the overall ratio of fuel and air consumed by the engine. Thus the patch is made to have a spark ignitible mixture strength even though the overall mixture is leaner than would be ignitible.

The mixture ratio control of load depends on this patch burning. In an experiment, an electromagnetic sample valve was installed in an engine cylinder. The engine was operated at moderate load so that a patch of limited size was formed. Gas samples were taken by the sample valve at various times in the cycle. Fig. 5 illustrates the cylinder arrangement and the composition of the gas samples obtained at various times in the cycle.

The variations in composition of the gas samples with sample valve timing clearly suggest the swirling of a patch of combustion products past the sample valve. It will be noted from the gas compositions that the combustion in the patch was quite complete by the time the patch reached the sample valve on its first turn around the cylinder. The fluctuations of gas composition also give an indication of the rate of air swirl.

Controlling Knock Elimination

The elimination of combustion knock is obtained in the Texaco Combustion Process by limiting the the residence time of combustible mixture at combustion chamber pressures and temperatures. Practically, the necessary limitation of residence time involves a coordinated consideration of the relative location of the injector and spark plug; of the direction and character of the fuel spray, and of the relative timing of injection and ignition. It has been desirable to define the limits of residence time that permit knock-free operation in these specific terms.

Injector and Spark-Plug Location

As the distance between the injector and spark plug is increased, a larger patch of mixture is built up before ignition can take place, until finally the

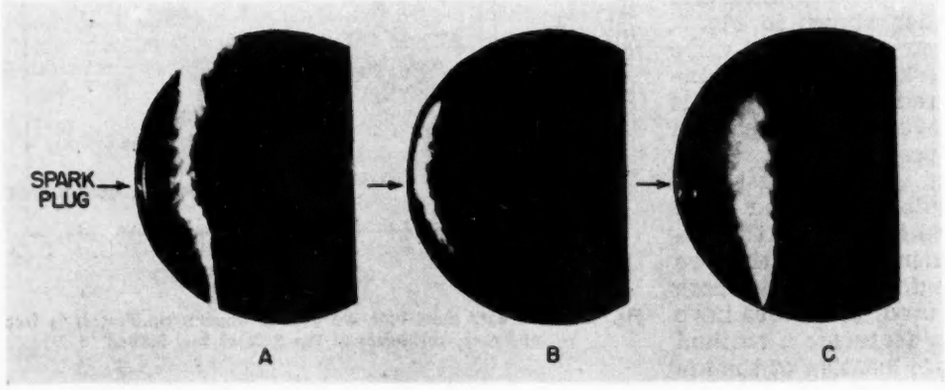


Fig. 6—These photographs of spray characteristics reveal that the spray in A is too penetrating so that it passes the spark plug; the spray in B is deflected too much by the swirling air; and the spray in C is satisfactory since it produces a good combustible mixture near the spark plug

patch becomes so large that in some remote portion of it the permissible residence time is exceeded and knock occurs. Experiments have demonstrated that knock-free operation may be obtained with the spark plug located between 30 and 60 deg downstream of the injector. With the plug at 90 deg, knock-free operation was borderline, and beyond 90 deg, knock occurred. While the injector-spark plug positions must be selected in accordance with the basic idea of limiting residence time, these results indicate a reasonable latitude in the choice of location.

Direction and Character of the Fuel Spray

Proper fuel-spray characteristics are also important in obtaining knock-free operation. Fig. 6 shows three sample stroboscopic photographs of sprays from different nozzles as observed five crankangle degrees after the beginning of injection under engine conditions of air swirl and compression.

Photograph A shows an unsatisfactory spray which penetrates so far and in so concentrated a beam that it has passed well beyond the spark plug. By the time the combustible mixture has been carried to the plug, too large a patch will have accumulated and knock will occur.

Photograph B shows an unsatisfactory spray which is deflected so much by the swirling air that it forms a concentrated zone of rich mixture very close to the combustion chamber wall. The mixture at the plug may be so rich as to prevent ignition.

Photograph C shows a satisfactory spray which produces a good combustible mixture in the region of the spark plug. The spray is strong enough that it is not deflected excessively by the swirling air and at the same time is not so penetrating as to pass beyond the plug before ignition.

The range of sprays that will result in knock-free operation is relatively broad.

Relative Timing of Injection and Ignition

The third factor affecting knock elimination is the relative timing of injection and ignition. Fig. 7 illustrates the coordination of these events. For knock-free operation a spark must exist at some time during the period designated as "ignition tolerance." If the spark has died out before this period commences, the engine will either misfire or fire by compression ignition depending upon the quality of the fuel. If the spark does not start until after this period has passed, the patch of combustible mixture will be so large, and accordingly the residence time so long, that the occurrence of knock will be dependent upon the octane value of the fuel as in a carbureted engine.

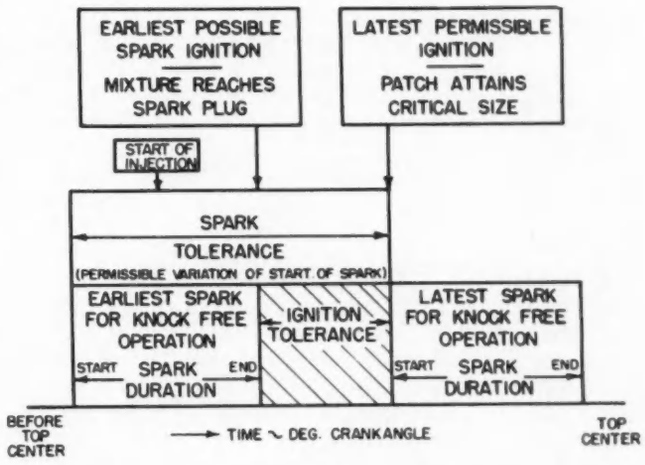


Fig. 7—Relative timing of injection and ignition for the Texaco Combustion Process

To avoid these conditions or, in other words, to operate on the Texaco Combustion Process, it is necessary that the start of the spark be somewhere within the period designated as "spark tolerance." This spark tolerance normally is from 15 to 30 deg of crankangle for engines equipped with a conventional automotive ignition system.

Further consideration of Fig. 7 supports an observation that spark timing, within its tolerance, has a negligible effect on power output. In one case, where the start of the spark occurs prior to the onset of the ignition-tolerance period, ignition can occur at but one time—the time when the mixture reaches the plug. In the other case, where the start of the spark falls within the ignition-tolerance zone,

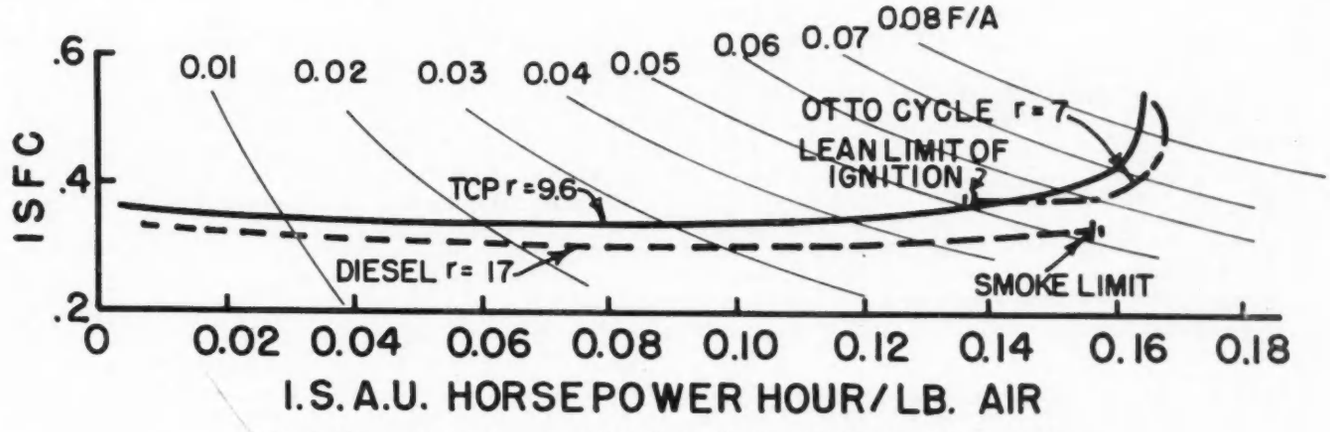


Fig. 8—Comparative performance of Otto Cycle, diesel, and TCP automotive size engines

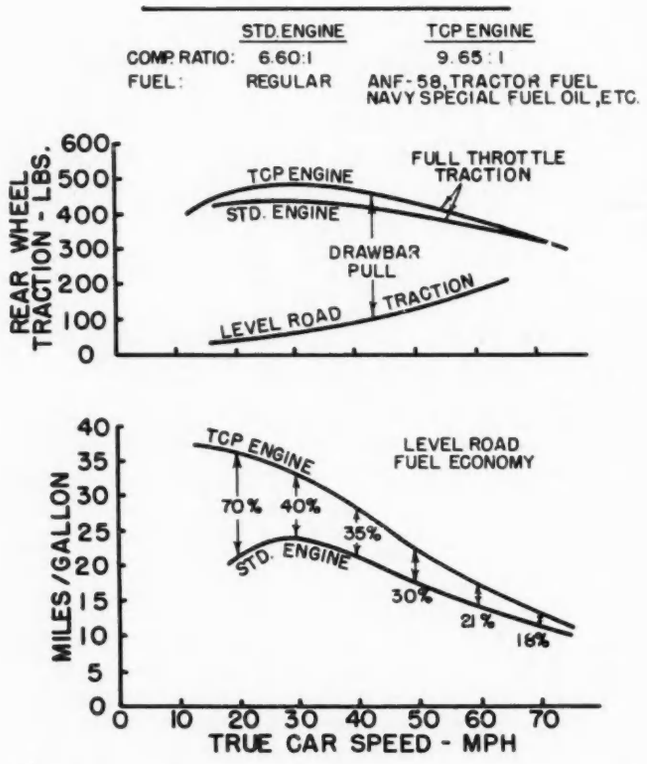


Fig. 9—Comparative high-gear performance of a popular car, powered by its standard engine and a naturally-aspirated TCP engine

the timing of ignition depends on spark timing. No power change is noticeable in this case, however, because the flame quickly reaches the same fixed flame-front position which it takes with earlier spark timing. Thereafter, combustion is controlled by injection exactly as in the first case.

It is apparent then that spark timing is dependent upon injection timing and may not be considered an independent variable. The spark tolerance is so liberal, however, that a fixed timing is often satisfactory over the entire speed-load range of the engine.

Taken altogether these three factors—the location of the injector and spark plug, the direction and character of the fuel spray, and the timing of injection and ignition—allow for margins of error that are commensurate with the requirements for construction, servicing and use of engines.

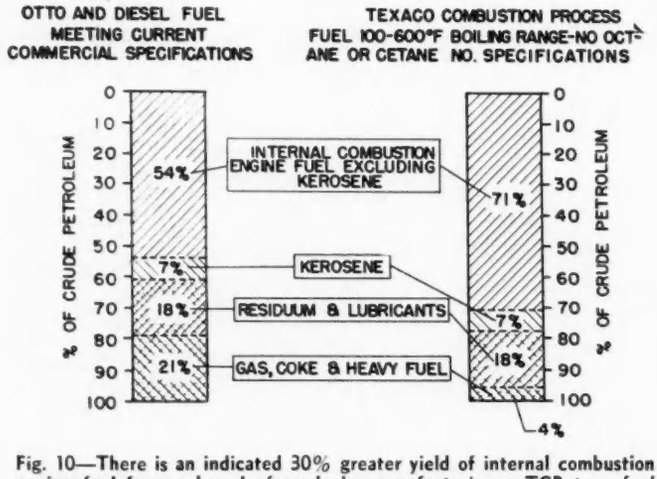


Fig. 10—There is an indicated 30% greater yield of internal combustion engine fuel from a barrel of crude by manufacturing a TCP type fuel as against fuels meeting current gasoline and diesel fuel specifications

Comparative Indicated Performance

Light is shed on the relative performance of the Otto cycle, diesel, and TCP engines by a comparison of their utilization of fuel and air. Fig. 8, a plot of indicated specific fuel consumption (isfc), expressed as pounds of fuel per indicated horsepower-hour, versus indicated specific air utilization (isau), expressed as indicated horsepower-hours per pound of air, is particularly suitable for this comparison. The latter expression is, of course, proportional to indicated horsepower once the air consumption of the engine is known. This plot uniquely defines the performance of an engine, since both variables are determined by the mixture strength and the corresponding value of thermal efficiency.

The Otto cycle, as may be seen, operates at high output and high fuel consumption, and is limited on the lean end by misfiring. The diesel engine on the other hand operates at low fuel consumption, but also in a lower range of output, never attaining the high output of an Otto cycle engine. The TCP curve covers the range of both of the other cycles and merges them into a single curve which approaches both the low fuel economy of the diesel and the high output of the Otto cycle. Thus, the TCP combines in a single operation the two best features of Otto and diesel engines, namely, the high part-load fuel economy of the diesel and the high full-load power of the Otto cycle engine.

Comparative Car Performance

The information now at hand, without considering the possible future developments, is sufficient to consider a multicylinder TCP engine for operation in an automobile and to make an accurate estimate of its resultant performance. The most elementary form of TCP engine—four cycle, poppet valve, naturally aspirated—will exploit a minimum of TCP's potential. However, it offers a fair basis for a preliminary comparison.

Fig. 9 shows a comparison between the high gear performance of a popular automobile powered by its conventional 6.6 compression ratio engine and by a TCP engine. Although doing so somewhat minimizes TCP's performance advantages, the TCP performance is predicted on using the same bore, stroke and gear ratio as the conventional engine. From Fig. 9 it is apparent that the TCP engine will at least equal the full throttle performance of the conventional engine; and that, with normal driving habits, the fuel economy of the TCP engine will be of the order of 30% greater than with the conventional engine. The conventional engine requires a "regular" motor fuel, while the TCP engine would operate on a fuel having no octane number specification and a broad boiling range.

At one time or another during the development

work, TCP engines have been operated extensively on fuels meeting specifications for motor gasoline, diesel fuel, ANF-58 jet engine fuel, tractor fuel, aviation gasoline, Navy special fuel oil, and so forth. It appears that any of these might be used as desired.

If a fuel were to be made for TCP engines, it should be predicated on maximum yield from crude oil and on minimum processing losses and costs. A clean fuel, of some 100 to 600 F boiling range and having no octane or cetane number specification would be suitable to the engine and near to maximum availability. As an example, the data presented by Fig. 10 has been prepared to show yields of internal-combustion engine fuel obtained in two cases: (1) when manufactured to 1946 commercial gasoline and diesel fuel specifications, and (2) assuming manufacture of a fuel of the type considered for TCP.

It will be noted from Fig. 10 that there is a significant improvement in the yield of internal-combustion engine fuel in the latter case. An example, such as the above, involves a certain degree of uncertainty as to how far it applies in general practice; and doubtless certain exceptions can be found, depending on the properties of the crude petroleum to be processed and the refinery equipment available for that processing. This particular example was for an actual crude which is in good supply and the processing proposed is that of a large and modern refinery. The example is thought to be inidcative of the general situation.

Paper on which this abridgment is based is available in full in multilithographed form from SAE Special Publications Department. Price 25¢ to members, 50¢ to nonmembers.

Discussion

Notes TCP Similar To Hesselman Engine

From discussion by

A. W. Pope, Jr.,

Waukesha Motor Co.

Since this paper on the Texaco combustion process and the earlier papers on the same subject delivered some years ago in Paris and in the Journal of the Franklin Institute make no reference to the Hesselman engine, it seems advisable to present a more complete account of the spark ignited injection engine story, that the basic principles of the Hesselman engine be outlined. Unfortunately the man best able to do this is no longer living. He was Mr Torbjorn Dillstrom of the Hesselman Co. who spent several years in this country during the early commercial development of the Hesselman engine, and presented a paper on the subject at the SAE Summer Meeting at Saranac Inn, June 20th, 1934. I will, therefore, attempt to point out the relation of the Hesselman to the Texaco engine.

Understood Air—Fuel Relationships

First it should be pointed out that Mr. Hesselman was a distinguished pioneer in the diesel field, and before diesel engines had obtained any wide usage in this country, his diesel patents were issued on air swirl to obtain efficient fuel-air mixture in full diesel engines. These patents illustrate Mr. Hesselman's very comprehensive understanding of the relation of air movement to fuel combustion.

When Mr. Hesselman undertook the development of the spark diesel, the primary objective was the development of a *low pressure* engine, an engine which would not appreciably raise the pressures of carburetor type engines of that day. His problem was to lower the ratio, not raise it. He already knew how to handle high compression ratio efficiently.

The Hesselman patent illustrates a combustion chamber with spark plug adjacent the injector similar to the diagrams in the Barber paper, but in a low pressure engine where detonation is not a problem, combustion is more efficient if the fuel is allowed to make a pass around the chamber to be better prepared for combustion before the spark occurs. The Hesselman patent stresses the feature of air-fuel preparation before ignition. But the claims are quite broad and apparently are not limited by prior art to the detailed description of the specification.

Mr. Dillstrom's SAE paper at Saranac in 1934 indicates a broad understanding of the spark ignition-injection engine principles. Shortly after the Hesselman engine got into commercial production, they were faced with demands for increased power and efficiency. This involved raising the compression ratio and reversing the trend of the original purpose of the low pressure Hesselman engine. Dillstrom's thinking along this line can best be stated by quoting from his SAE paper:

"In the spark ignition, fuel injection engine the charge is formed at a certain time before the spark occurs, and this makes it possible to mix the fuel and air thoroughly whereby high output is secured. Engines operating on fuel oil with a compression ratio of 7.5:1 have given bmep over 125 psi.

"The fuel is not injected until at the end of the compression stroke, and thus is not unduly heated by the heat of compression. A higher compression ratio can therefore be employed in this engine than in the carburetor engine without pre-ignition or detonation. The engine thus works in an efficient cycle."

Quotation is from SAE Journal, December 1934, p. 431, paper given at SAE Summer Meeting at Saranac, June 20th, 1934. This statement of Dillstrom's indicates that he had a good conception of the air-spray-spark relationship.

FIVE DIESEL VALVE

DIESEL engine valves suffer five maladies: (1) breakage, (2) seat wear, (3) valve face guttering, (4) stem and guide wear, and (5) sticking. Remedy for these troubles lies in recognizing fundamental causes that apply in a given case and using all available knowledge to eliminate them.

Valves break because of high loading and valve weaknesses. High loading stems from factors such as wear in valve train, overspeeding, high lash, cam design not matched to valve gear, cocked springs, and out-of-round seats. Valves of sound structural design and of material inadequate at operating temperatures also tend to break.

Seat Wear and Guttering Sources

Seats will wear if materials are incompatible, unit loadings are high, and materials inadequate. Leakage from out-of-roundness and broken-away deposits, as well as materials that cannot withstand environment, bring on valve face guttering.

Valve stems and guides will wear due to poor geometry of lubrication and wrong materials and finishes. Valves stick because of stem and guide deposits resulting from too high an oil temperature, scanty oil supply, or excesive stem-to-guide clearance.

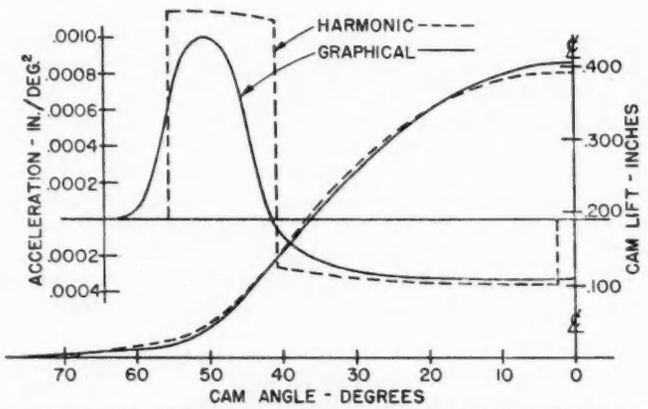


Fig. 1—Lift and acceleration diagrams for graphical and harmonic cam designs. The harmonic design impact in the valve gear. The graphical design reduced tappet stress and increased lift

Valve Breakage

Valve breakages can result from improper installation as well as borderline designs. Improper installations are difficult to trace unless repeated; but borderline designs can be traced since the failures are usually of the fatigue type. Fatigue breakages may occur at several locations on the valve depending upon design. Causes that will lead to this form of destruction are: (1) abnormal loading of the valve, or (2) a design which lends itself more readily to fatigue failures.

Abnormal loading can result from overspeeding the engine, or may be present after wear has occurred in valve train parts, increasing lash. The manufacturer designs a valve train for a given set of operating conditions; but engines differ in their ability to operate well when these conditions are varied.

Rpm Increase Breaks Valves

Overspeeding, while not common in diesel engines, can occur if the engine is used in a vehicle, especially downhill, or if the operator adjusts the engine so that higher speeds may be obtained. One known case was that of an operator who found he could move a much heavier load if the engine was operated 200 rpm higher than normal. But the engine broke valves when operated at this higher speed.

Manufacturers are charged with the responsibility for designing valve trains with a factor of safety for overspeed. To design a valve train for higher speeds, it is necessary to consider more than just the structure of the valve, even though the valve might be the weakest member of the valve train. An improved valve in this instance may result in a slight increase in life before the breakage occurs at some other point on the valve or in the valve train.

One remedy which has resulted in raising the normal operating speeds of engines successfully is

TROUBLES

• What Causes Them

• What Relieves Them

EXCERPTS FROM PAPER* BY

Vincent Ayres, Assistant Chief Engineer, Valve Division, Eaton Mfg. Co.

* Paper "Valve Problems in Diesel Engines," was presented at SAE Summer Meeting, French Lick, Ind., June 6, 1950.

to improve the valve motion. A study of the valve train deflections will uncover any weaknesses in the system. Such a weakness may be found in the push-rod, rocker arm, rocker shaft, or rocker shaft support. If the thought is kept in mind that rigidity is more important than weight in diesel valve trains, the next step can be approached.

It is redesigning cam contour to eliminate excessively rapid changes of acceleration, which are kin to impact. Turkish[1] in his valve gear design treatise discusses a semi-graphical method of cam design. By this method, a slightly modified lift curve designed with an eye on the acceleration diagram can reduce theoretical impact values from infinity to values which the valve train can withstand without undue deflection and vibration. This type of cam design is now common in automotive gasoline engines and is gaining use in diesel engines.

Graphical Versus Harmonic Design

Fig. 1 shows typical lift and acceleration diagrams for graphical and harmonic cam designs. The designs used for illustration are the old and new provided on a diesel engine having approximately 200-cu in. displacement per cyl operating at 1200 rpm. The harmonic design included a dwell of 5 deg at the nose joined by nose radii of 0.130 in. The acceleration of the harmonic design was typical with square corners. Theoretically, this design requires the gear to change from zero acceleration to maximum acceleration in zero degrees.

Force is equal to mass times the acceleration; and if the latter is changed at a very high rate, then the force is changed also at this rate. This is known as impact. In a valve gear it is actually a blow which starts the gear vibrating. This vibration will have amplitude, frequency, and rate of decay proportional to the striking force, stiffness, and damping characteristics of the system. It is not uncommon to have this vibration exist all through the lift cycle and cause high valve seating impact with possible breakage.

Since the cam determines the motion, it can be made to push instead of strike the valve gear. The graphic design shown requires approximately 10 deg cam travel to change from zero to maximum acceleration and pick up a load of 250 lb. A higher maximum acceleration is possible with this type of contour because the rate of load application is low, but a lower acceleration was used in this instance. The cam angle is wider, but the lift curve is only slightly affected. By eliminating the dwell and increasing the nose radius to 0.222 in., the lift was increased and the tappet stress reduced.

Measurement of actual loads in the valve train with a resistance wire strain gauge on the rocker arm or push-rod is recommended as a means of comparing designs. Abrupt changes of load are easily detected and improvements in cam design will evidence themselves by a smoother loading diagram, more closely approaching the theoretical, and in freedom from extreme changes of load value.

Other benefits may be reduced value spring load requirements, reduced spring vibration and breakage, and larger cam nose radii. All these gains reduce tappet face stresses, reduce camshaft torques which benefit timing gear life, and lower valve train noise through the speed range.

Wear in the valve train parts may contribute to

[1] Valve Gear Design, by M. C. Turkish, pp. 7, 70, and 117.

breakage if the velocity of valve seating is increased. Minor effects are seat wear which might occur on the tappet face, cam lobe, rocker arm, valve tip, or valve guide and dishing of the valve.

In computing required ramp heights for cam designs, consideration is given to lash and the amount of ramp required to compensate for maximum cooking of the valve; but if these values are increased through wear, then the designed ramp height becomes inadequate to control valve seating. Use of hydraulic lifters as a means of lash control has been accepted by the industry. In conjunction with improved cams, it has contributed toward reduced valve breakages.

Valve Structure

A study of successful valve designs will disclose some common features. Departures from these tenets might show up as valve weakness.

The valve head section should be rigid enough to support the gas load without undue deflection. Mass of the valve head may not be the complete answer, since the strength of the valve material at the operating temperature is also involved.

The valve rim should not be too thin because a thin section will have a greater temperature fluctuation, leading to a thermal fatigue evidenced by cracking, splitting, or curling.

A decently wide seat contact is good practice, with as little of the valve head as possible extending beyond the seat into the combustion chamber. A large portion of the valve heat is carried through this contact.

A generous underhead radius, with no abrupt changes in section at the junction of the head and stem, will reduce the concentration of stresses in this area. Fatigue failures in this area are seldom eliminated by adding large masses of steel. Much more can be gained by eliminating the cause of the high loading, using a higher strength material, and lowering valve temperature.

Valve guide length and position have an effect on valve temperatures and motion. A guide length of not less than 50% of the total valve length, evenly spaced, is a good rule of thumb. Most engines have guides longer than this. Lowest valve temperatures in the critical area beneath the head are obtained when the guide boss and cooling water jacket are brought close to the valve head. Port cross-sections may become unsymmetrical and casting difficulty experienced; but results are worth a good try.

A lock ring in a groove on the valve stem can prevent a valve falling into the combustion chamber if the valve spring breaks. Damage to the engine can still result, however, if valve to piston clearances are close. Bending loads, resulting from out-of-square springs or other causes, concentrate stresses in the lock ring groove. Valve stem fatigue failures at this point may disappear with the elimination of the groove. After all, valve springs should also be designed so that they do not break.

On the other hand, the breakage then may be transferred to the valve keeper groove. Keeper designs of the double or triple bead type, Fig. 2A, will concentrate these same bending loads in the first groove toward the guide. I cannot recall ever seeing a failure on one of these designs which occurred in the second or third groove. A design which grips the valve so that the bending loads are taken on the full diameter, Fig. 2B, will greatly increase the life, or cause the failure to occur in some other place.

Another possibility is a design which allows the

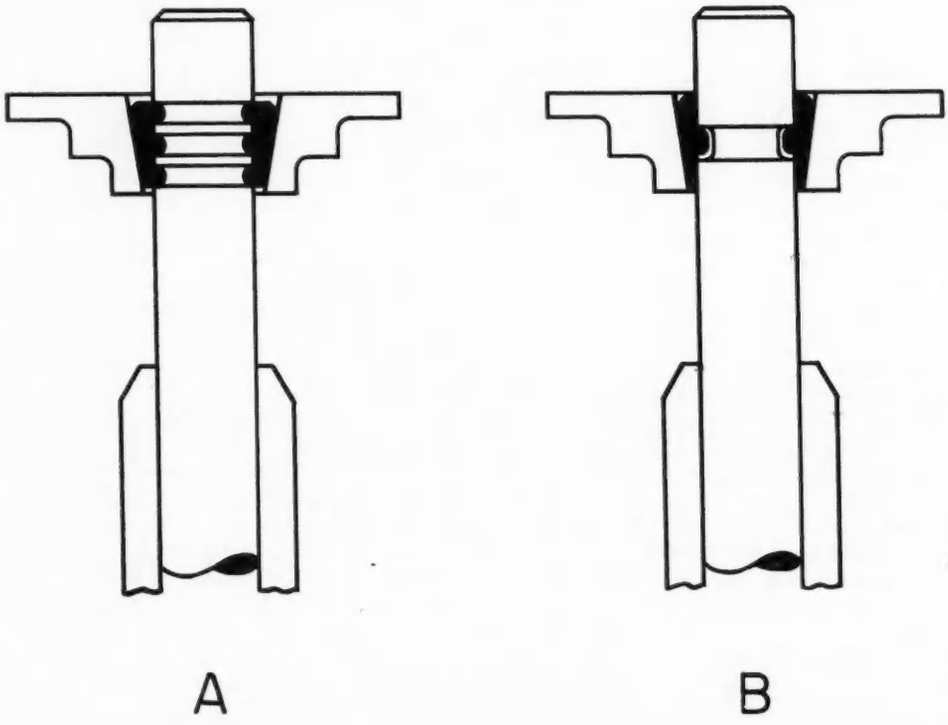


Fig. 2—Double or triple bead keeper designs, as in "A," concentrate the bending in the first groove toward the guide. Bending loads are taken on the full diameter in the design in "B"

spring retainer washer to equalize the load by tilting on the valve stem. This precludes the use of wedge type keys which lock tight, and instead introduces relative movement with its hazards of wear.

Valve Materials

Valve materials may be selected on the basis of (a) strength at the operating temperature, (b) hardness at the operating temperature, and (c) resistance to environment. The choosing of valve steels should not be considered as a mysterious activity, but is sometimes placed in this category due to the mystery surrounding the item of valve operating temperatures.

Testing to determine actual valve operating temperatures is not extremely difficult and values within 50 deg are obtainable. I refer here to the property of hardness loss with temperature of certain steels. A valve steel, such as silcrome No. 1, can be fully hardened to approximately 58 Rockwell C, and it will lose hardness when subjected to temperatures above 900 F. The hardness will be in the neighborhood of 20 Rockwell C when a temperature of 1550 F is reached. In between these points a 100 F variation will change hardness about four points.

While this method may seem crude to exacting scientists, it is accurate enough to serve as a comparative test to determine the benefit of any design changes in lowering temperature. Surely if such changes will not show up in this test, they cannot be expected to produce extended valve life.

Valve temperatures might be divided into zones and classed as cool, temperate, and hot. Cool means below 1200 F; temperate is the range of 1200 to 1400 F; and hot is above.

Classification makes the selection of valve steels, on the basis of hot strength or fatigue resistance, relatively simple. All the commonly used valve steels have good strength in the cool zone; and none has good properties at temperatures above 1450 F. The reason for sodium cooling any valve—gasoline or diesel—is to drop its temperature into the temperate zone or lower. Steels to operate in the cool zone are chosen with regard to ability to resist environment (corrosive or oxidizing atmosphere) and for economy. Inlet valves, and a few exhaust valves, are in this group.

Engine builders already know that austenitic steels have better stength properties than hardenable steels in the temperate zone. Proof is in the fact that the majority of diesel exhaust valves are made of austenitics.

A common belief is that since these materials cannot be hardened by heat-treatment, there is no point in heat-treating. Hot strength, however, can be improved, as illustrated in a comparison of creep tests on austenitic steel alloys, with and without heat-treatment. Fig. 3 shows the gain in creep resistance of several austenitic steels in the temperate zone.

While the tests charted are not on valve steels, the comparative improvement is evident by the increase in stress required for 0.1% stretch in 1000 hr. Austenitic valve steels show response to heat-treatment in similar manner; but a stepped-up method of testing has been used to reduce test time without affecting results.

Fig. 4 illustrates the improvement of hot stretch

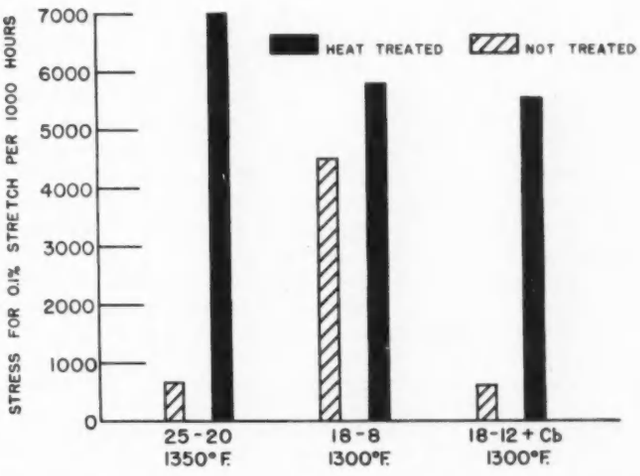


Fig. 3—Heat-treatment can increase the resistance to creep of austenitic steels, these test data show

resistance resulting from heat-treating austenitic valve steels. Validity of this test method has been checked by comparing engine valves of the materials shown, with and without heat-treatment. The use of nitrogen-bearing 21-12 has reduced dishing and breakage. That is why it is being specified for many engines.

Hardness of austenitic steels cannot be increased to any marked degree with heat-treatment; but it may be reduced by the same heat-treatments that improve hot strength. This indicates that a balance of desired properties must be sought.

The severity of this test is too great for steels of the hardenable or semi-austenitic types, such as silcrome No. 1, silcrome x-be, or xcr, for these materials will stretch, dish or break in some engine operating conditions where the austenitics will not.

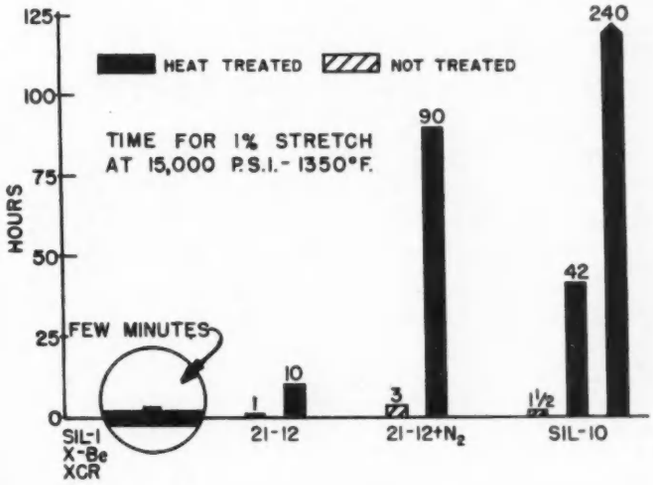


Fig. 4—Hot stretch resistance of austenitic steels improves with heat-treatment

This further attests to the validity of such a test. Fig. 4 shows the time for these steels as only a few minutes since they start stretching as soon as the load is applied. Reliable figures can be obtained with these materials if the stress is cut way down, or if they are run at a lower temperature.

A milder form of the problem of breakage, lack of hot strength, may show up as dishing of the valve head rather than breakage. This dishing may result in loss of lash and subsequent valve seat leakage, which raises the temperature. Proper choice of materials here is also essential.

Austenitic steels have lower coefficients of heat transfer and higher coefficients of expansion, which must be considered in the engine design.

Seat Wear

Seat wear in diesel engines has been a problem for many years, with the greatest number of failures occurring on the inlet side. There are two possible explanations for this occurrence. One is that there may be different materials in the two ports because of the necessity of using a better steel on the exhaust for other reasons. This better material can be either a high alloy exhaust valve steel or some other corrosion resistant alloy, such as stellite or eatonite, which may also have a property of abrasion resistance better than the inlet valve.

The other possibility is that the exhaust valve is coated with deposits resulting from combustion. These deposits act as an insulating layer and prevent intimate contact between the exhaust valve face and the cylinder head seat.

The deposits seem to be most significant since it is a known fact that materials to be rubbed together without lubication must be selected for this property. Most of the inlet wear, unless caused by dirt, occurs not on the valve but on the seat in the cylinder head. It might be called fretting, scuffing, or microscopic welding. The rate of wear in some cases has been known to be as high as 0.001 in. per hr.

Peculiarly, the wear may not occur on all valves in the cylinder head, and some cylinder heads may have an extreme amount of wear on one valve with none on another. This, apparently, is not a function then of metallurgical differences from one cylinder to another, but is more an operating difference, such as the amount of relative distortion from one port to another and one cylinder head to another. If distortion is found to be the cause, the use of other materials or a change in the cylinder head sections surrounding the valve might reduce wear. That this is true is evidenced by the fact that some manufacturers have eliminated wear by changing cylinder head structure. Others, unfortunately, have gotten into the wear problem by making such a change.

Distortion creates wear by causing the valve to contact only a small portion of the cylinder seat when contact is first made at seating. The valve then either slides or is forced by cylinder pressure into full contact, provided the seat is still round. This small movement at high pressure is the start of fretting or roughening of the valve or seat. It is aggravated by poor valve motion and bad mechanical conditions which allow misalignment. A change of seat angle may give relief. For example, if distortion is lateral, a 15-deg seat angle valve would be unseated much less than a 45-deg valve.

Mating Materials

Use of a different material combination has to date been the most positive means of reducing wear. Its effectiveness has not been 100% and what works in one engine may not work in another. The choice of materials is limited to cast iron for the seat, unless the manufacturer resorts to the use of a seat insert, and the valve materials. Considerable testing is involved in choosing the right combination and the medicine may be bitter from the standpoint of cost.

Some valves have shown reduced wear of the valve face or cylinder seat face when allowed to rotate; others have shown more wear. Rotation should be noted in conjunction with this problem and, if beneficial, incorporated.

The use of coatings on the face of the valves or cylinder head seat remains to be exploited. This refers to such things as tinning, which is done sometimes on other engine parts to eliminate scuffing.

Hardening of the cylinder-head iron has shown benefit; but high valve hardness has not been very effective since the greater amount of wear is usually on the cylinder head, particularly if no insert is used.

The direct application of stellite on the cylinder head is sometimes a salvage measure and often improves life.

Valve Face Guttering

Valve face guttering, on the other hand, has been primarily an exhaust valve problem. It might be considered as having two phases. One is the result of distortion which allows leakage to occur in one local area, or as a result of bad mechanical conditions. The other phase is the leakage which results when deposits, which have formed between the valve and seat, break away. Gasoline engines have been subjected to the formation of deposits, but the problem is relatively new for diesel engines.

What the future holds cannot be predicted. But indications are that lubricating oils containing high quantities of additives will increase the amount of deposit formation on diesel engine valves and there-

Table 1—Hot Hardness Value and Scaling Resistance of Various Steels

Material	Hot Hardness (Brinell)		Scaling Resistance (200 mg per hr)	
	950 F	1300 F	Oxidizing	Reducing
Carbon or Low Alloy	200	under 40	above 20,000	
Exhaust Valve Alloys				
SIL-1	(250)	40		
X-Be	254	40		
XCR	230	110	30 to	50 to
21-12	130-180	90-116	90	150
21-12 + N_2	130-180	90-120		
SIL-10	142	90		
Facings				
Stellite #6	(320)	(275)	less than	less than
Eatonite	(350)	(330)	20	15

by aggravate the problem of seat leakage. Additives in the fuel could further complicate the picture. Improving life under both of these conditions which cause leakage can be based on experience gained in improving life in gasoline engines.

A valve material selected for its resistance to environment is indicated. Table 1 shows hot hardness values for various steels. These values are an indication of resistance to pitting by indentation or deformation, which may lead to guttering. Temperatures of 950 F and 1300 F are used and the data from mutual indentation are given as Brinell hardness. In the temperate zone, the hard facing alloys, stellite and eatonite, are most useful.

The same chart rates the scaling resistance of these materials; but for simplicity, these are shown in three groups: (a) carbon or low alloy steels whose loss in scaling is 20,000 mg per 200 hr or greater; (b) valve steels with loss range of 30 to 50 mg per 200 hr; and (c) stellite and eatonite with values less than 20 mg per 200 hr. The relative scaling resistance of carbon steels or standard low alloys, like SAE 8645 and the valve steels, helps to explain why the low alloys are being replaced as inlet materials.

Experience on a few tests with high ash oils indicates that guttering on valves and seats of both inlet and exhaust can be caused when small areas of deposits break off. Guttering is straight high-temperature oxidation and not corrosion. Diesel engineers use exhaust gas temperature as an indicator. But they do not realize that high-pressure high-temperature leakage can create 1500 F valve temperatures without affecting exhaust gas temperature, which might be as low as 800 F. Thirty to 50 hr of full output running (with a narrow leakage area) can cause bad guttering on valve steels, whereas upwards of 250 hr are required with a hard facing under the same conditions.

Fuels, Lubes Induce Deposits

Guttered valves, even when hard faced, are possible with present fuels and lubricants. This indicates that a close watch on temperatures is required. One valve returned to us for comment had a bright shiny appearance at the seat contact with a couple of guttered areas. But after electrolytic cleaning the gutters were no longer present. The steel showed practically no effect of the leakages and the deposit which formed the seating surface was entirely gone.

Here, again, rotation has proved of benefit in keeping temperatures, deposits, and leakage under control. Rotators are relatively new in diesel engines; but the gains in valve life may well justify the expense of incorporating a device which will allow valve rotation.

Stem and Guide Wear

The problem of stem and guide wear is essentially no different than other problems of engine wear. It is a function of three things: (1) materials and hardnesses, (2) load, and (3) lubrication.

Use of special materials, heat treatments, and coatings has shown some merit. Several manufacturers are using valve guides which have been ferroxed or parco-lubrized with a degree of success. Size and surface finish are also important and proper valve train geometry must not be overlooked.

The most effective element in freedom from wear is adequate lubrication, assuming that the aforementioned factors are given recognition. Past experience has indicated that nearly any material combination will be successful, since the loads are light, if given a reasonable amount of lubrication. But very few materials will operate satisfactorily in a dry state. The problem becomes one of maintaining satisfactory lubrication on both exhaust and inlet valves without over-lubricating the inlet valve, and thereby increasing oil consumption, or under-lubricating exhaust valves as a result of scanty oil supply or deposits.

An oil seal ring on the inlet valves coupled with close stem-to-guide clearance, may effectively satisfy the inlet valve requirement. An ample oil supply on the exhaust with the minimum possible stem-to-guide clearance for effective control and improved heat transfer may be the most satisfactory. Excessive stem-to-guide clearances hamper transfer of heat from valve to cooling medium and allow room for deposits to form, which reduce effectiveness of lubrication.

Valve Sticking

The problem of sticking has been placed at the end of the list since it might be classed more as a nuisance problem on diesel engines. Sticking results from building up of deposits on the valve stem, causing it to be sluggish in the guide or, in some cases, causing it actually to become wedged to the point of not operating. If the valve sticks in an open position, it may be struck by the piston and damage the engine. At this point it is more than a nuisance.

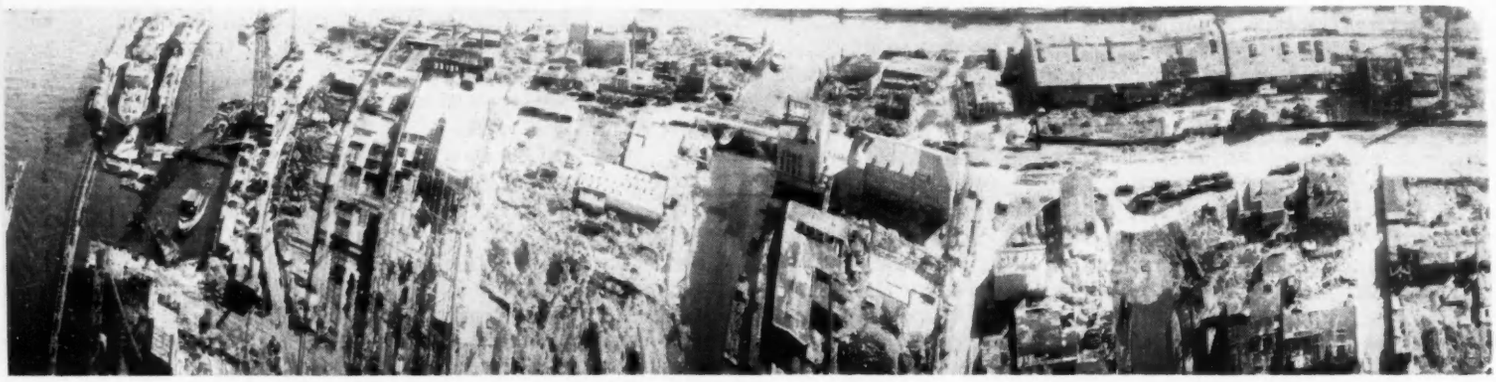
The problem may be approached from two directions. First, do not provide any space for deposits to form, that is keep stem and guide clearances to a minimum. Any spaces that are available for deposits to form should be as wide as possible so that these deposits can reach their maximum normal thickness without obstructing the movement of the valve. An example is the use of counterbores in the valve guide. If used, they should be large enough to allow the deposits to build up and break off before they will wedge.

It is better still to reduce the guide length, so that the point of first contact between the valve and guide occurs where the temperature is low enough not to cause oil breakdown to form deposits.

Oils which have reduced deposit tendencies are recommended; but the most effective elimination of valve stem sticking is the use of a device which allows the valve to rotate.

Solvents on valve stems to remove gummy formations has been tried successfully by some engine builders. One had a passage leading through the valve guide and cylinder head to the outer deck next to the valve spring, and periodically a solvent was forced into this passage. Subsequent use of a release type rotator showed such benefit that it was adopted in production.

Paper on which this article is based is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.



Stereo Strip Camera Has

Across the top and bottom of this spread are shown sections of pictures obtained with the stereoscopic continuous-strip aerial camera.

Although two separate pictures are shown here, in actual practice the two images are superimposed, so that they look like a fuzzy double exposure. Then, when special polaroid glasses are used to view the picture, the images unscramble and give the effect of a three-dimensional view of the scene.

The images are taken on a continuous strip of film, as explained in the text, so that a narrow print many feet long can be obtained that covers a long strip of territory . . . such as the whole length of Manhattan or a long stretch of beach. If a positive film is made to be used for projection, the strip can be run through the projector in a continuous operation.

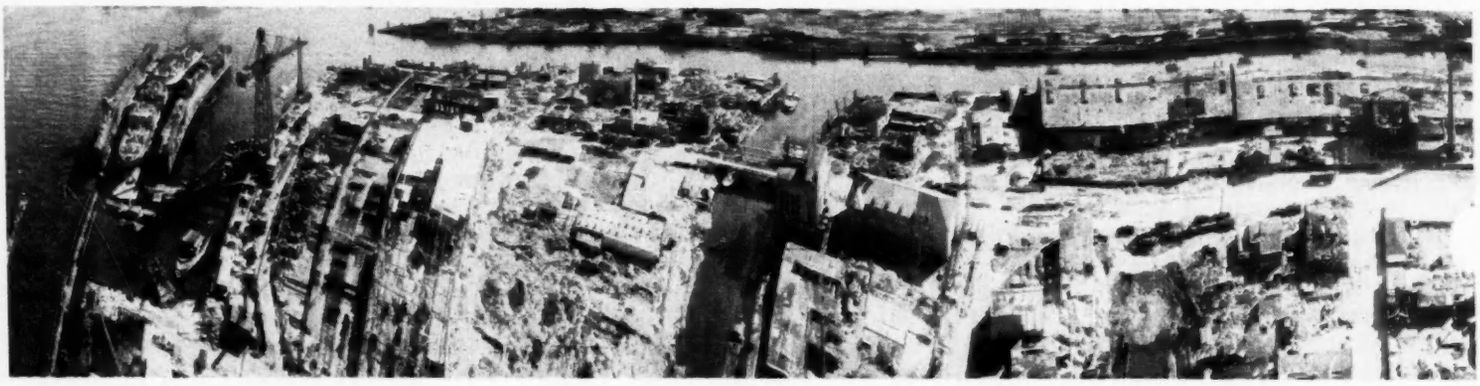
Then each object in the picture comes on the projection screen from one side and moves across the screen until it disappears off the other edge. Of course, the projector film winding motor can be stopped at any time, to allow additional study of a particular region.

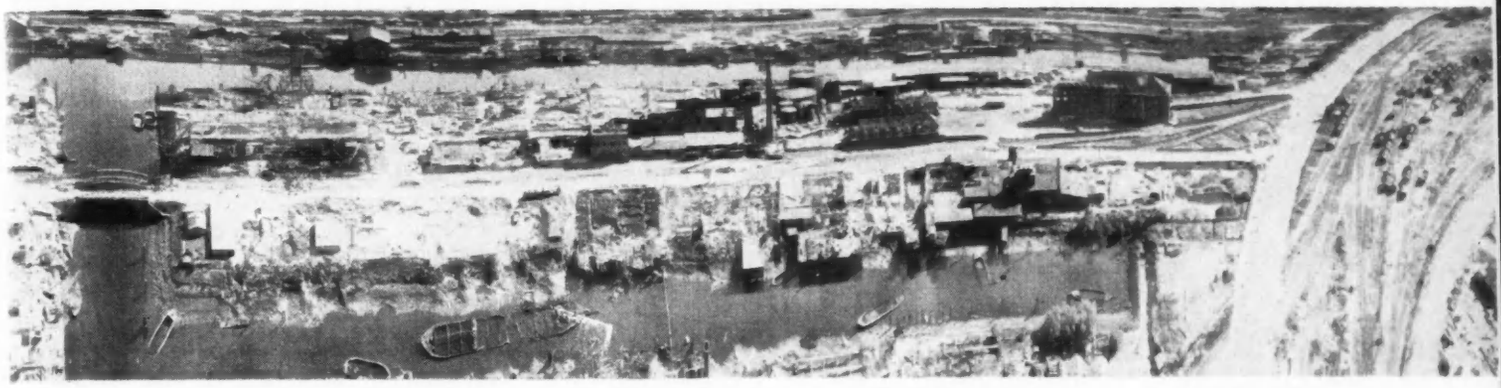
THE parlor stereoscope—common in homes of 50 years ago—has long since gone out of fashion but, during the last war, the basic principles of stereophotography were used in the development of a new form of photograph—called the vectograph—that allows buildings, military emplacements, depressions, and the like to stand out in the pictures in bold relief.

This technique was combined with another photographic development—the continuous-strip aerial camera, projector, and height finder—which allows a stretch of territory many miles long to be photographed as one unbroken picture.

Applications

These vectographs, which may be taken in black and white or in color, are of inestimable value in planning military operations, such as briefing purposes and evaluating the amount of bomb damage





Military, Civilian Uses

BASED ON PAPER* BY

Col. George W. Goddard, Chief, Photographic Laboratory, Wright-Patterson Air Force Base

* Paper, "Stereophotography," was presented at the SAE National Aeronautic Meeting, New York City, April 19, 1950.

to targets; as an aid to assault parties and the like; for tactical planning over unmapped or sketchily mapped territory; and for conveying intelligence information to field officers.

Vectographs are also used for training purposes, to show, in relief, the cones of gunfire from aircraft, screening candidates for rangefinder operations, three-dimensional views of equipment, and so on.

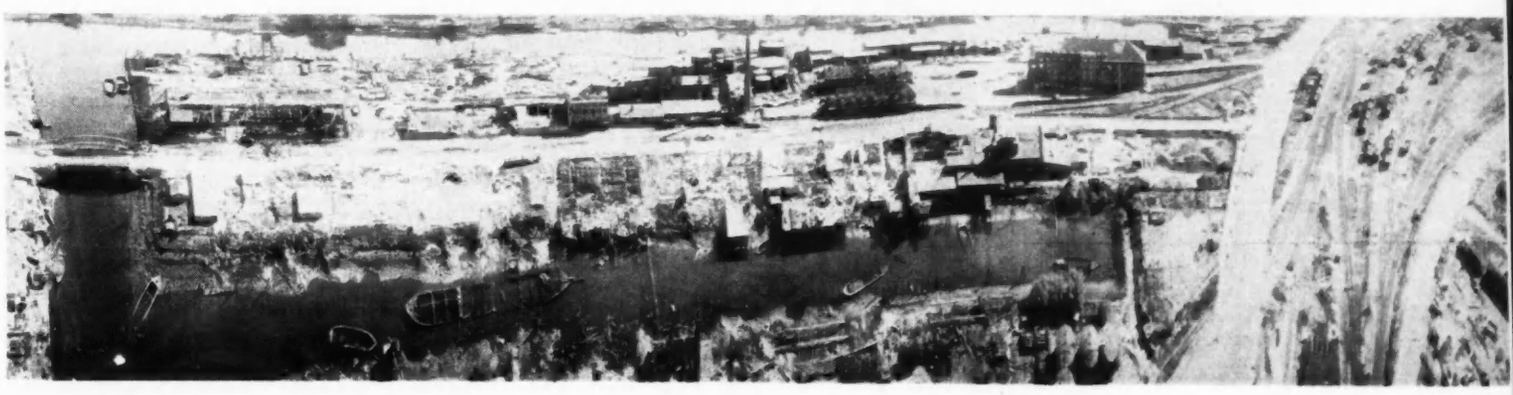
When a special type of film is used in the stereo strip camera, enemy camouflaged installations are easily detected. This film has two layers of emulsion: one is infrared, which records natural vegetation, because of its chlorophyl, and the other is a panchromatic layer, which records the unnatural foliage and spectral enamel paints used in camouflage netting, tanks, guns, and the like. Then, the natural vegetation is seen on the screen in red and the unnatural in blue. These pictures permit the interpreter to see military equipment hidden in woods, under nets, and many things not detectable in conventional photographs.

The camera also has many peacetime uses. For the past four years, it has been used extensively with the magnetometer in the search for oil and minerals. It has been used in connection with railroad, highway, and pipeloine surveys. Airport runways have been photographed at low level to determine the size of cracks and the general condition of the concrete.

Other commercial uses include: the determination of types and height of trees in forests; estimating the crops at certain times of the year; to give flood control data; to aid in pest control; complete railway right-of-way coverage to study possible improvements.

Principles of Stereophotography

We see objects in relief because our eyes are placed so that both see, to a large extent, the same



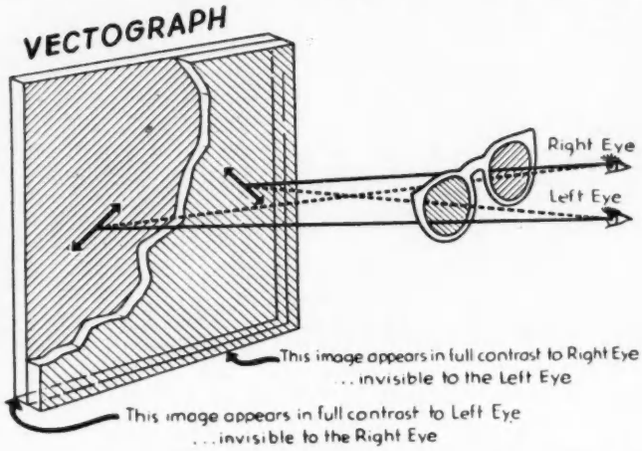

VECTOGRAPH
Right Eye
Left Eye
This image appears in full contrast to Right Eye
...invisible to the Left Eye
This image appears in full contrast to Left Eye
...invisible to the Right Eye

Fig. 1—Vectograph-polaroid method of viewing aerial photographs in three dimensions

objects in their field of view, but so that each eye gets a slightly different view of the objects, when they aren't too far away. These two slightly different views are interpreted by the brain to give the sensation of relief.

In stereophotography two views are taken from slightly different points so that when the prints are viewed in the stereoscope—or even without such an instrument, if the eyes are properly trained—the objects depicted stand out in relief, just as they would to the person viewing the original scene.

For ordinary stereo work the two points are separated by the distance between the eyes—2¾ in.—but when objects are far away, as is the ground from a plane flying at photographic heights, the two pictures must be taken at a distance apart much greater than that between the eyes. This may give an exaggerated appearance of relief that makes buildings seem higher and depressions deeper than they actually are, but pictures taken in this way are much easier to use and study for intelligence purposes.

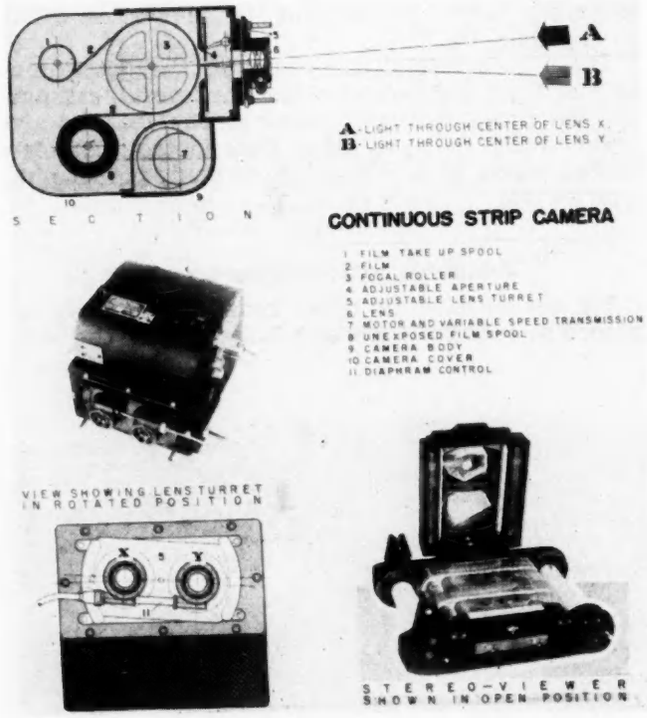


Fig. 2—Continuous-strip camera and viewer developed for modern high-speed low-altitude three-dimensional photography

Three-Dimensional Vectograph

Vectographs are three-dimensional pictures in the form of single prints or of positive transparencies for direct viewing against a light source or for projection on a screen. They were developed because earlier three-dimensional pictures required special viewing stereoscopes, which limited the size of the area that could be viewed in each pair of pictures and allowed only one person to look at them at a time.

In the vectograph the two images that are necessary to give the three-dimensional effect are placed one over the other, so that if they are looked at by the unaided eye, they seem like a fuzzy double exposure.

When special glasses are used to view them, however, the images are unscrambled, so that each eye sees its own perfect picture, just as with the old stereoscope.

This effect is possible because a special emulsion has been used, which allows each image to be rendered in terms of "degree of polarization" rather than in pigment, dye, or silver particles. In other words, as shown in Fig. 1, each image is polarized so that its "optical slots" are parallel to those of the polarizer used in one of the eyepieces of the viewing spectacles and are perpendicular to the "optical slots" of the polarizer in the other eyepiece.

In this way, but one image can be seen by each eye, for the other one is blocked off from that eye by the polarizing effect.

Continuous-Strip Camera

The continuous-strip camera is shown in Fig. 2 and its method of operation in Fig. 3. The camera is equipped with a pair of matched lenses, which photograph two 4½-in. tracks on aerial film 9½ in. wide and 200 ft long.

The lenses are set with the optical axis located on the right and left sides of a 0.004-in. slit in the camera, over which the film travels, synchronized with the speed of the airplane. A 16-mm camera is mounted in the cockpit to record, for each second of the photographic run, the absolute altitude, air speed, time, and azimuth, as this information is necessary in making height and depth calculations.

The camera operates best with high-speed aircraft flying at altitudes ranging from 300 to 1500 ft. This is called "on-the-deck flying," and is considered, at the moment, the best flying altitude to avoid radar detection and antiaircraft fire.

Synchronization of film speed to airplane speed over the ground is obtained with an image motion compensation device directed through the undersurface of the airplane. It consists of two photoelectric cells located 3 in. above a gridded glass

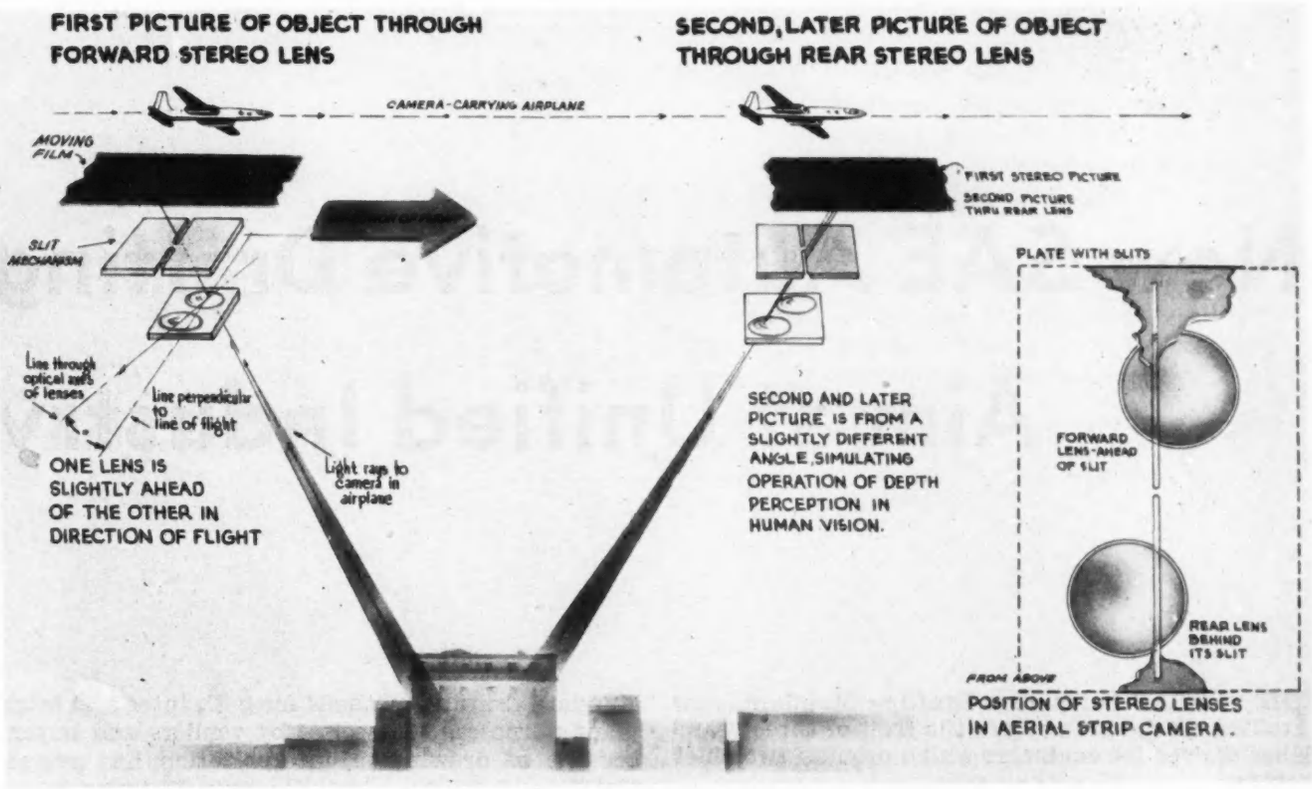

FIRST PICTURE OF OBJECT THROUGH FORWARD STEREO LENS
SECOND, LATER PICTURE OF OBJECT THROUGH REAR STEREO LENS
CAMERA-CARRYING AIRPLANE
MOVING FILM
SLIT MECHANISM
Line through optical axes of lenses
Line perpendicular to line of flight
ONE LENS IS SLIGHTLY AHEAD OF THE OTHER IN DIRECTION OF FLIGHT
Light rays to camera in airplane
SECOND AND LATER PICTURE IS FROM A SLIGHTLY DIFFERENT ANGLE, SIMULATING OPERATION OF DEPTH PERCEPTION IN HUMAN VISION.
FIRST STEREO PICTURE
SECOND PICTURE THRU REAR LENS
PLATE WITH SLITS
FORWARD LENS-AHEAD OF SLIT
REAR LENS BEHIND ITS SLIT
FROM ABOVE
POSITION OF STEREO LENSES IN AERIAL STRIP CAMERA.

Fig. 3—Theory of stereo strip aerial photography for high-speed jet aircraft at supersonic speeds

plate. As the airplane flies along, the reflections of objects through the gridded plate bounce from one photocell to another, setting up frequencies that are fed through an amplifying system to the motor film winding system in the camera.

On one test using a Lockheed P-80 jet, equipped with the electronic synchronizer, the plane flew at 500 mph at 50 ft and photographed a sergeant with a hand of playing cards spread out on the runway. The various cards were easily identifiable and there was no distortion, indicating there was perfect synchronization.

Auxiliary Equipment

The auxiliary equipment used for interpretation consists of a viewer through which data can be taken either from a positive roll of film using transmitted light or from paper strips of pictures using reflected light.

Attached to the viewer is a stereocomparator, which is the key instrument for making differential height measurements of objects on the ground, beach gradients, and underwater determinations.

Also supplied with the strip camera is a stereoscopic projector, constructed quite similar to the camera, with two lens duplicating the camera lens parallax angle (Fig. 4). Color or black-and-white transparencies are projected on an aluminized screen and viewed with the polarized glasses. Polaroid film screens are located back of each lens in the projector, and the same area of picture is projected one upon the other, on the screen.

This paper is available in full in multilithographed form from SAE Special Publications Department. Price 25¢ to members, 50¢ to nonmembers.

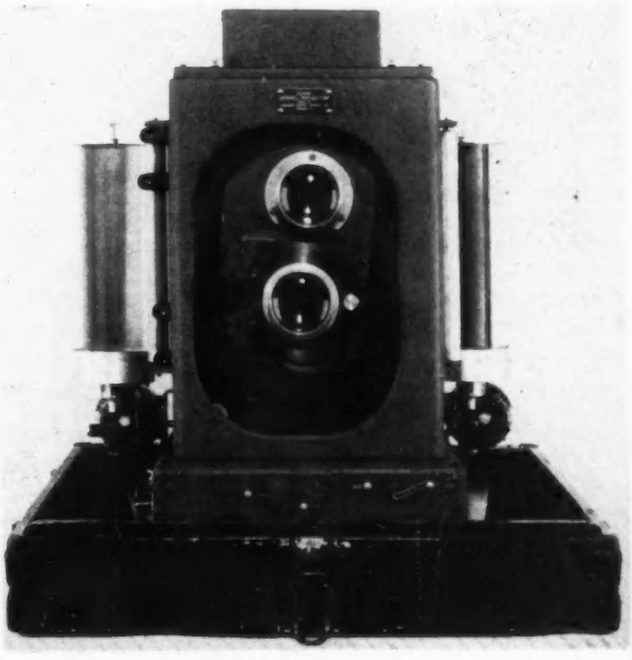


Fig. 4—Special projector for projecting oblique and vertical stereo pictures using polaroid system

New SAE Automotive Drafting Aim at Unified Industry

THE new SAE Automotive Drafting Standards now rolling off the presses, are the fruit of three years' labor of over 100 engineers which promise two chief gains:

1. It is hoped they will promote drafting practice uniformity within the industry to simplify supplier-purchaser relationships.

2. Military production, if ever needed on a large scale, could be speeded with a unified drafting practice.

Automotive men have long felt the need for standard drawing methods for both inter and intra plant purposes.[1] Time lost by vendors and buyers because of drawing misinterpretation has proved costly and irksome. At times, even factory men of given companies have found difficulties understanding the drawings of their own engineering departments. Serious as they are in peacetime, these de-

[1]Automotive Drafting Standards is not the only SAE effort in this field. Also published by SAE is the SAE Aeronautical Drafting Manual, now in its second edition.

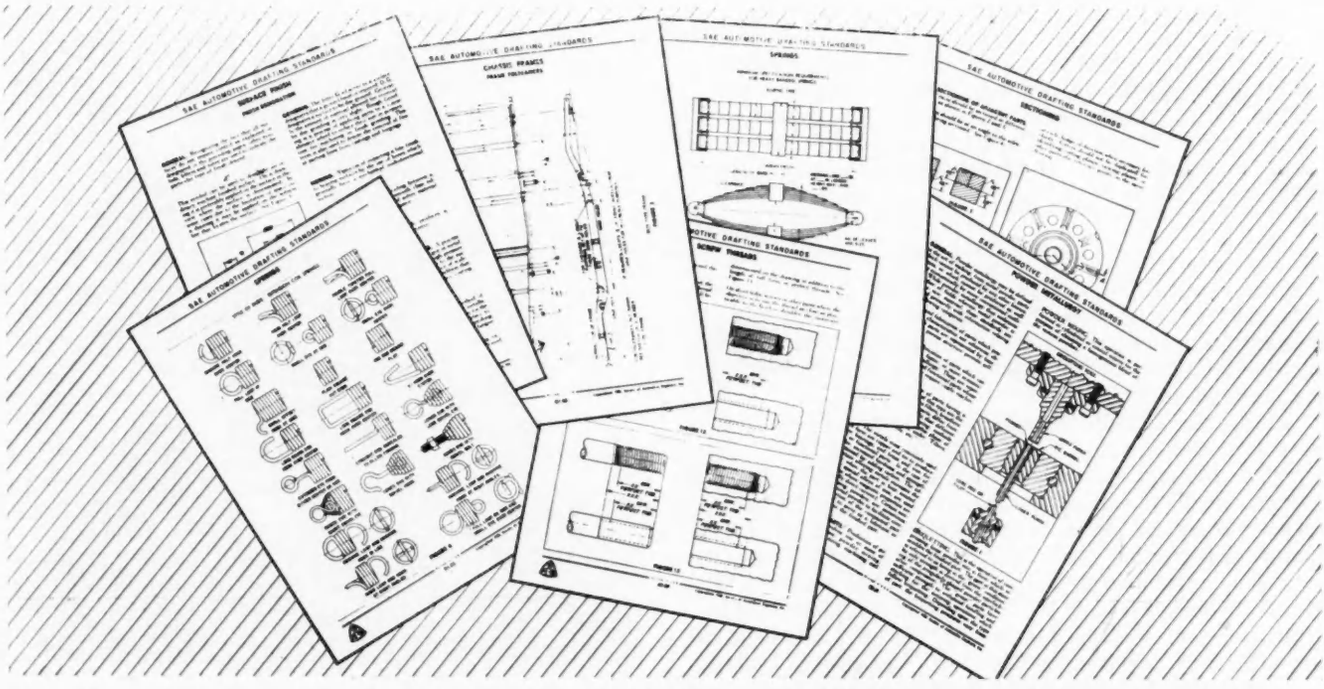
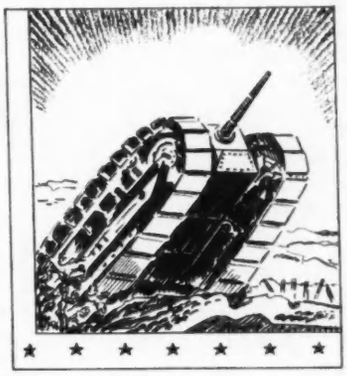


Fig. 1—These are typical pages from both parts of the newly-published SAE Automotive Drafting Standards. The first part deals with fundamentals; the second, with drafting practices for specific type parts, such as springs, castings, and chassis frames

Standards Practice



Growing threat of all-out military production brings these new drafting standards into sharp focus. War materiel often is required in quantities demanding the participation of several manufacturers.

Time is of the essence and bottlenecks due to misunderstandings of "blueprint language" can penalize production schedules, as World War II proved.

lays are even more critical during war production.

Such impediments to production efficiency can be largely minimized by a standardized drawing language, believe members of the SAE Automotive Drafting Committee. This group, which developed the Standards, is headed by W. A. Siler, Delco-Remy Division, GMC. So that the SAE Standards can do such a job, these men have selected the most acceptable practices in their compilation, consulting with draftsmen and engineers in all phases of the ground vehicle industry.

The Standards, to be issued within the next few weeks, are divided into two main parts—fundamentals of automotive drafting practice and specific SAE Automotive Drafting Standards. Fig. 1 shows some of the pages from both parts.

The automotive drafting fundamentals reflect the industry's practice on basic drafting elements. Detailed here are the rudiments of lettering, sectioning, projections, and dimensioning. The two-place decimal dimensioning system, which some automotive manufacturers are now using, also is presented. Another chapter is devoted to screw threads. Ways of designating and drawing the new Unified threads are among the items covered here. The drafting fundamentals section also includes chapters on drawing revisions, layout, and checking.

The Committee sees the drafting fundamentals section as a useful publication for teaching drafting in colleges and technical schools. It feels that this publication can supplement basic drafting texts in preparing engineers and technicians for the automotive industries.

Part II of the SAE Automotive Drafting Standards delineates procedures in more specific areas. It shows how to prepare drawings for castings, die castings, springs, powered metal parts, and chassis frames, and how to specify surface finish. Expansion of this section is contemplated for the future. The Committee invites suggestions and comments on both parts.

The SAE Automotive Drafting Standards, including Parts I and II, will be available from the SAE Special Publications Department for $3.00 to SAE members and $6.00 to nonmembers. It will be in looseleaf form, with three holes punched in the left side of each leaf. Part I, Fundamentals of Automotive Drafting Practice, will be available separately for $1.50 to SAE members and to universities and students for classroom use, and $3.00 to nonmembers. This separate publication of Part I only will not be punched, but will be bound and stitched. Quantity prices are available for both publications.

A looseleaf binder for the SAE Automotive Drafting Standards also will be available for $2.00.

The project was initiated by the SAE Technical Board under the sponsorship of D. G. Roos, Past-President of the Society and vice-president of Willys-Overland Motors, Inc. When Roos' term on the Board expired in 1948, he was succeeded as sponsor by A. G. Herreshoff, Chrysler Corp. Serving on the Committee with Chairman Siler are: W. L. Barth, General Motors Corp.; N. L. Bean, Ford Motor Co.; M. L. Carpentier, Chrysler Corp.; R. G. Cummings, Ford Motor Co.; Harold Fisher, Bendix Products Division, Bendix Aviation Corp.; Prof. J. Gerardi, University of Detroit; C. A. Hubert, International Harvester Co.; E. F. Jirsa, John Deere Waterloo Tractor Works; L. R. Jones, Studebaker Corp.; H. L. Keller; R. S. Kellogg, Packard Motor Car Co.; F. G. Kerby, Budd Co.; F. K. Lane, Truck and Coach Division, GMC; H. A. Marchant, Chrysler Corp.; F. L. Mills, Willys-Overland Motors, Inc.; G. L. McLain, Chrysler Corp.; R. M. Neff, Chevrolet Motor Division, GMC; Prof. R. T. Northrup, Wayne University; and C. N. Thompson, A. O. Smith Corp.

Consultants and liaison representatives on the Committee are E. W. Bryan, Standards Branch, General Staff, Department of Defense; Lt.-Col. A. D. Gough, Standards Branch, Logistics Division, Department of the Army; E. C. Duval, Air Materiel Command; Col. R. J. Hogan, Office of Chief of Ordnance; and O. E. Kirchner, American Airlines, Inc.

MOTORED SIMPLIFY

A MOTORED engine is a valuable combustion research tool because it eliminates the complexities of a fired engine for such investigations. Merit and versatility of the method were shown by studies demonstrating the effect of cool flames on knock and supporting the autoignition theory of knock.

Studying knock with an operating engine under knocking conditions is complicated experimentally by two factors: (1) existence of the flame front in the cylinder, and (2) difficulty of isolating the end gas, or last portion of the charge to burn.

In a motored engine, no flame front exists since no spark is passed; and the entire charge in the cylinder can be subjected to physical conditions met by the end gas in a fired engine. Because it eliminates these two experimental difficulties, the motored engine makes an ideal reactor for end gas reaction studies.

Investigations show that the motored engine technique is suitable for studying precombustion reactions. They disclose that precombustion reactions in a motored engine are affected by physical and chemical variables in the same way that these variables affect knock in a fired engine. This is summarized in Table 1.

Cool Flame Investigations

When hydrocarbon-air mixtures are subjected to elevated temperatures, partial oxidation reactions occur which sometimes manifest themselves by very faint blue luminescence. Because this luminescence occurs in the absence of combustion in the usual sense of the word, the phenomenon has been termed cool flame radiation.

Many investigators believe that the reactions which occur during luminescence and cool flames in tubes and bombs and those leading to knock in an engine are essentially the same. But this has not been proved in engines.

To understand better the role of cool flame reactions under the physical conditions peculiar to engines, motored engine investigations of these reactions were made. This was done by studying the effects of pertinent chemical and physical variables on cool flame and autoignition limits.

Fig. 1 shows the cool flame and autoignition limit curves for a stoichiometric n-heptane-air mixture in terms of engine manifold pressure and compression ratio. The upper curve, A-B-C, represents the minimum manifold pressure and compression ratio conditions for occurence of autoignition. The curve B-D indicates the minimum conditions for the occurence of cool flames. The shaded area B-C-D enclosed between the two curves defines the maximum and minimum conditions for cool flames; cool flames will occur at any set of motored engine operating conditions represented by a point in this area.

A striking point of the autoignition limit curve, A-B-C, is that at low compression ratios a much larger change in manifold pressure can be tolerated without autoignition than is the case at high compression ratios.

Table 1—The Correlation Between Motored Engine Precombustion Reactions and Fired Engine Knock

Physical Variable Increased or Chemical Variable Added	Precombustion Reactions in a Motored Engine	Knock in a Fired Engine
Inlet mixture Temperature	Increases	Increases
Compression Ratio	Increases	Increases
Maniford air pressure	Increases	Increases
Fuel octane number	Decreases	Decreases
Antiknock compounds	Decreases	Decreases
Proknock compound	Increases	Increases
Sulfur to a leaded fuel	Increases	Increases

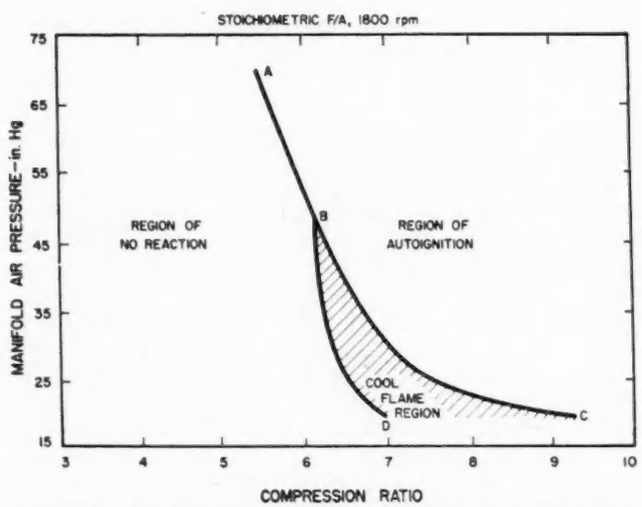


Fig. 1—Ignition curves for n-heptane in terms of engine operating variables. Cool flames will occur in the shaded area

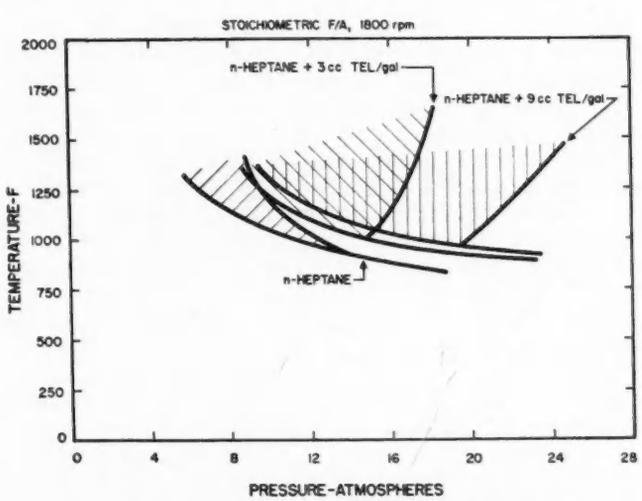


Fig. 2—Tetraethyl lead tends to broaden the cool flame zone, advancing the autoignition limit toward higher pressures

ENGINE STUDIES KNOCK RESEARCH

EXCERPTS FROM PAPER* BY

D. L. Pastell, Petroleum Laboratory, E. I. du Pont de Nemours & Co., Inc.

* Paper "Precombustion Reactions in a Motored Engine," was presented at SAE Summer Meeting, French Lick, Ind., June 5, 1950. This paper will be printed in full in SAE Quarterly Transactions.

The addition of 3 cc and 9 cc per gal of pure tetraethyl lead to n-heptane markedly changes the position of the ignition curves, as shown in Fig. 2. It is evident that the addition of tetraethyl lead:

1. Displaces the lower cool flame limit curves a significant, but not large, amount in the direction of higher pressure.

2. Displaces the upper cool flame (or autoignition limit) curves markedly in the direction of higher pressures.

Because the lower cool flame limit curves are only slightly displaced, while the autoignition curves are displaced by a large amount, the addition of tetraethyl lead has a third effect of broadening the physical conditions for existence of cool flames. It makes necessary more severe engine operating conditions before the cool flames can be made to pass into autoignition.

To show what the physical conditions of this plot mean in terms of actual fired engine operation, the data of Fig. 2 have been reproduced in Fig. 3. Two curves have been added showing the end gas temperature and pressure conditions attained in a fired engine for a series of different engine operating conditions.

The upper curve represents the calculated end gas conditions of a fired engine operated at 30 in. manifold pressure and four different compression ratios. It must be emphasized that each point on this curve represents the calculated maximum temperature and pressure reached by the end gas in a fired engine at the various compression ratios indicated. Therefore, the curve is not representative of the path followed by the end gas for a single engine cycle. The lower curve represents the corresponding fired engine end gas conditions when the engine is operated at 50 in. manifold pressure.

These curves show that the autoignition limits, as determined in the motored engine, occur in the same temperature and pressure regions to which the end gas is stressed in a fired engine. Moreover, these curves emphasize the importance of the observed effect of tetraethyl lead in extending the upper cool flame limit substantially in the direction of higher pressures, thus permitting the operation at higher compression ratios.

Since the addition of tetraethyl lead to a fuel

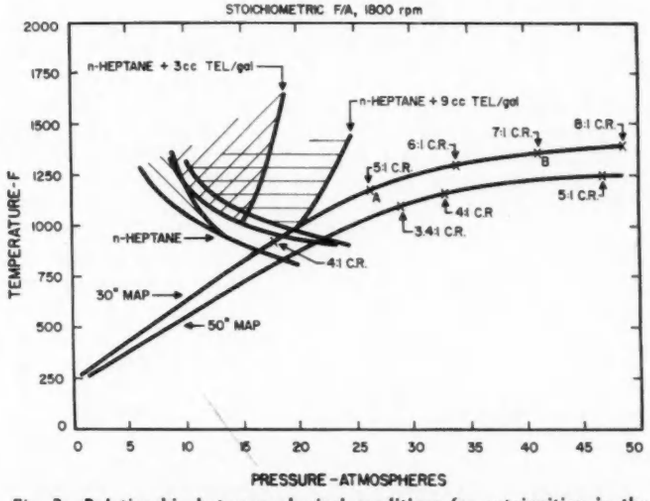


Fig. 3—Relationship between physical conditions for autoignition in the motored engine and end gas physical conditions in a fired engine

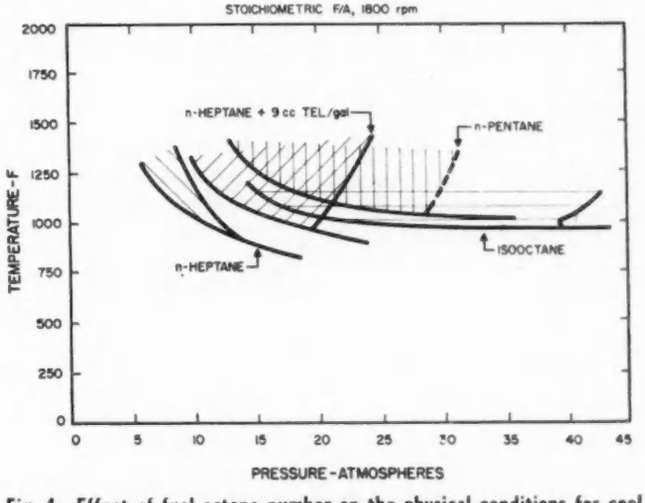


Fig. 4—Effect of fuel octane number on the physical conditions for cool flames and autoignition

has an important effect on the physical conditions necessary for cool flames and autoignition, it is to be expected that a correlation exists between the octane number of the fuel and the position of the ignition curves. Fig. 4 is a temperature-pressure plot of the ignition curves of four different fuels, including the curves for n-heptane and and n-heptane plus 9 cc pure tetraethyl lead per gal. The n-pentane curve also is shown since it has the same Motor Method octane number as the leaded n-heptane (62 octane number).

The ignition limit curves for iso-octane (100 octane number) are also illustrated in Fig. 4. This hydrocarbon has a much larger cool flame region than any of the other fuels shown, and the autoignition limit occurs at much higher pressures. It is both interesting and significant that the lower cool flame limits for both iso-octane and n-pentane fall in approximately the same temperature-pressure regions, yet iso-octane must be stressed to much more severe engine motoring conditions before sufficient reaction occurs to be detectable by pressure measurements. This may indicate that the precombustion reaction mechanisms are different for these two hydrocarbons.

Since antiknocks shift the ignition curves in the direction of higher pressures, it may be expected that pronock additives would shift the curves in the reverse direction. This is the case illustrated in Fig. 5 for two different proknock compounds. The addition of 0.46 weight percent ditertiary butyl peroxide (0.1 weight percent peroxide oxygen) to n-heptane has two effects. First, it displaces the autoignition curve toward lower temperatures at high pressures. Second, at low pressures it displaces both the autoignition and cool flame curves toward higher temperatures.

Autoignition and Trace Knock Correlation

The autoignition theory is probably the hypothesis most generally accepted to explain knock. It involves a physical interpretation of knock in terms of pressure, temperature, and time. According to this theory, if the end gas is subjected to critical physical conditions, autoignition will occur. Many investigations have been reported in support of this theory.

If precombustion reactions in a motored engine are similar to reactions leading to knock in a fired engine, and if knock can be interpreted in the light of the autoignition theory, then temperature-pressure conditions for autoignition in the motored engine may be expected to be the same as conditions for trace knock in a fired engine. The motored and fired engine data in Fig. 6 show this to be substantially the case.

The lower curve in Fig. 6 is the motored engine autoignition limit for n-heptane containing 3 cc tetraethyl lead per gal. The upper curve defines the temperature-pressure conditions for the occurrence of trace knock in the same engine during firing operation. In each case, engine speed was 1800 rpm.

The trace knock temperatures were calculated from the measured pressures by the method of Goodenough[1]. While this method probably is the best available, the temperatures calculated may still be appreciably in error. Also the autoignition temperatures using the perfect gas law is not exceptionally accurate, but is undoubtedly more accurate than the trace knock temperature calculations.

Considering the inherent errors in the temperature calculations, correlation of the two curves suggests that trace knock in the fired engine and autoignition in the motored engine probably result from similar precombustion reactions. It furnishes evidence in support of the autoignition theory of knock. The correlation also indicates that in a fired engine, radiation from the advancing flame front is probably not an important factor in conditioning the end gas for occurrence of knock.

In general, the other fuels tested show the same type of correlation between tendency toward knock in a fired engine and susceptibility toward autoignition in the motored engine.

(Paper on which this article is based is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

[1] See "Principles of Thermodynamics," Henry Holt and Co., 1931, p. 278, by G. A. Goodenough.

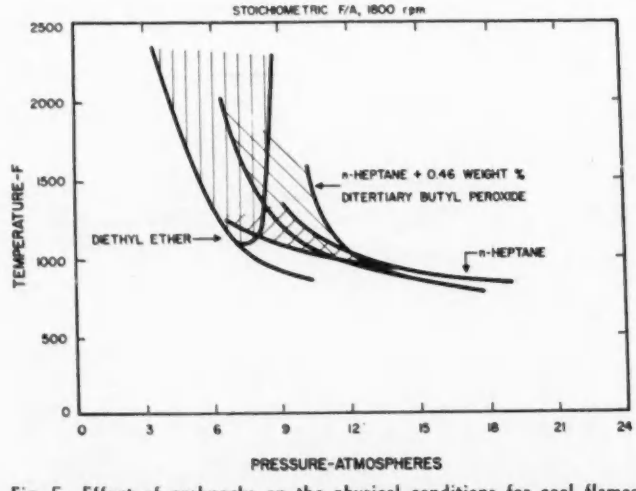


Fig. 5—Effect of proknocks on the physical conditions for cool flames and autoignition

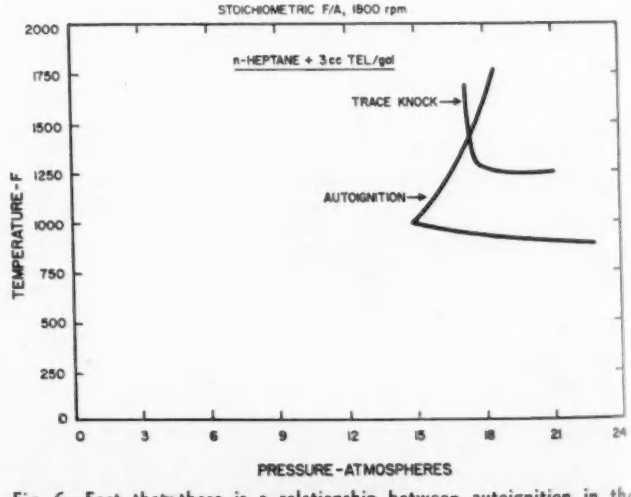


Fig. 6—Fact that there is a relationship between autoignition in the motored engine and trace knock in the fired engine tends to substantiate the autoignition theory of knock

TEAMWORK - A Must For Aero Standardization

EXCERPTS FROM PAPER* BY

J. H. Sidebottom, Aircraft Industries Association of America, Inc.
and
G. N. Cole, Pratt & Whitney Aircraft Division, UAC

* Paper, "Is Teamwork the Answer in Aeronautical Standardization?" was presented at the SAE National Aeronautical Meeting, New York City, April 19, 1950.

WE believe that history and experience in aeronautical standardization have proved the need for teamwork between our principal customer—the military—and the industrial producer or manufacturer. We have seen periods of divergence of opinions where industrial activity was carried on separately and exclusive of any military activity. We have noted periods of accelerated military standardization effort which was not closely correlated with the industrial effort. As Gen. B. W. Chidlaw said in 1947, "We have four possible ways of accomplishing the task: (1) let industry do it—with approval by the service, (2) let industry do it—period, (3) let the service do it with later coordination of industry, (4) let's do it together. It strikes me that the last one hits the jackpot."

Our experience since 1947 has certainly justified the general's conclusion. The operation of the Council for Military Standards (NASC) and the SAE committee E-25 program, under the ANI Powerplant and Propeller Standardization Agreement, have demonstrated what can be accomplished with teamwork.

In order that these teams may continue to work together, there must be a recognition and appreciation of the separate role which each team member must play. The Government must assume responsibility for rendering technical assistance in the field of tactical and strategic problems and in the realm of maintenance and supply. Industry must accept the responsibility for providing the technical know-how and answering the questions as to whether a standard can be made and whether it will work in the product involved.

The theory of voluntary self-regulation must predominate and be an accepted policy which governs the operation of the various committees and organizations engaged in the standardization effort.

We must maintain an enlightened industrial leadership in the whole field of standardization in order that the manufacturers may sense or anticipate the military needs. Industry must recognize and acknowledge military requirements, which in some cases will definitely compromise the most desirable design or manufacturing objective.

There is need for continuity of personnel in both the services and industry from the policy level down to the last technician involved in the development and maintenance of standards. Changing personnel and changing policies in this field have been problems which have retarded the standardization effort to date.

We firmly believe that the present philosophy of teamwork, as accepted by military and industrial people alike, is demonstrating that standardization on a national basis can be efficiently and economically achieved while serving the best interests of manufacturer and customer. We have concluded that it is the only philosophy which will continue to produce usable standards in consonance with the probably rapid technical progress to be expected over the years to come.

Historical Influence

History reveals that the aeronautical industry inherited and borrowed many good standardization habits from other fields but, during the early years of its life, it has suffered from the growing pains of organization and administration to an extent that has retarded the achievement of the real benefits of a truly national standardization effort. The tremendous development of aircraft for commercial and military purposes during the past 46 years has been, on the one hand, a deterrent to standardization of any type and, on the other hand, a great challenge to the engineering and production men who are determined to make this vehicle a useful

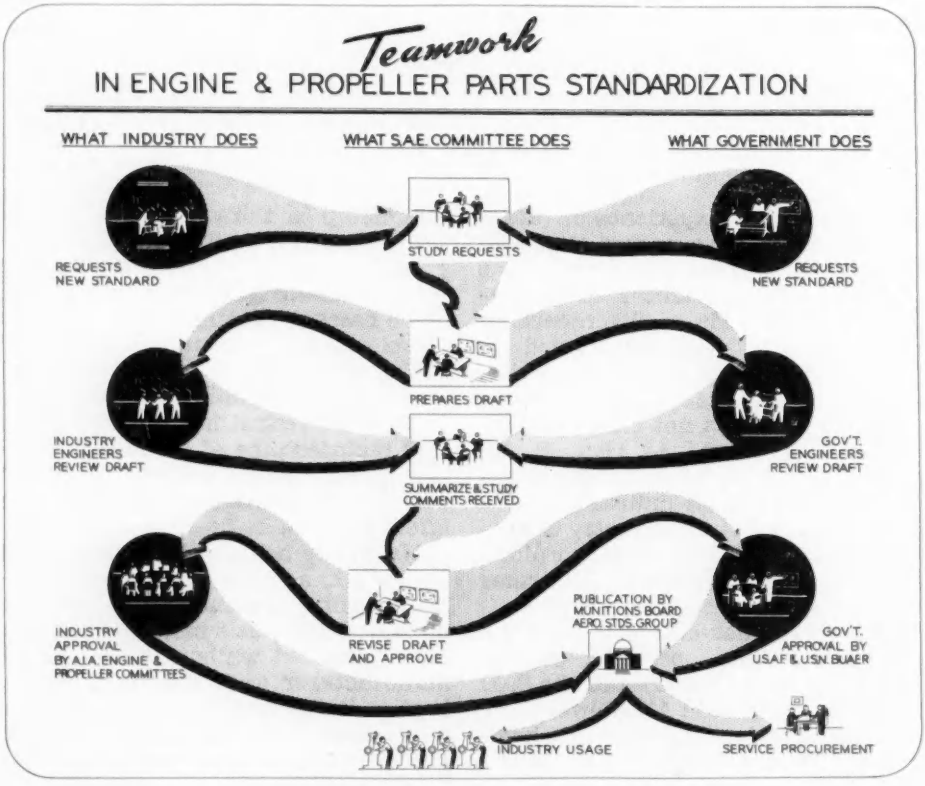
mode of transportation for all. The rapid technical development has been accompanied by frequent changes in military and civilian personnel at all levels of organization according to the ups and downs of the aeronautical business cycle. This factor has contributed to a lack of stability and continuity of policy on standards matters within the industry and military services. As a result, the attempts to organize aeronautical standardization on an industry-wide or national basis have generally failed.

1914–1922

During this period industry comprised a number of small companies primarily engaged in research, development, and experimentation, and not mass production of aircraft and aircraft parts. Prior to World War I, no real attempts were made to standardize aeronautical parts or procedures on a national basis. Although a semblance of organization for industry-wide standardization in the field was initiated during the World War I production period, the tremendous and concentrated effort on volume production of single-design engines and aircraft completely subordinated any real attempts to standardize parts applicable to several designs. The amazing story of the Liberty engine is indicative of these times and certainly shows the emphasis placed on production of a single-design product. The complete engine design was standard for all companies engaged in its manufacture, so there was obviously no need for industry-wide standardization of individual parts common to many designs as we think of it today.

It may be said that the need for standardization in this era scarcely extended beyond the company level, and even at that point was seriously deterred by the very nature of the business of building new vehicles by cut-and-try methods.

This early period was one in which the need for standardization was recognized, an objective policy was stated, but no real incentive for decisive action or implementation on the part of either industry or the military was found. The role of aircraft in military and commercial activity had not yet matured and the only national effort was the evolution of performance standards established for purposes of procurement by the Navy and Army air services. For example, as early as 1915 the Navy required a standard 48-hr type test for aeronautical engines and, during the accelerated production in World War I, these limits were continually raised as the standard of reliability improved.



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1922–1938

During this period, new companies and new designs of aircraft and engine types were formulated and great emphasis was placed on the diversity of aircraft uses. The military services were conducting design competitions for a great variety of aircraft, even including special speed racing models. By 1938 there was quite a wide choice of products in the aeronautical field, none of which might be considered to be more than prototype models. It

can be said of this era that very little stimulus from either military or commercial sources existed to improve or enhance the field of standardization in aeronautical equipment. An awareness of national and industry-wide objective in the field was just beginning to appear.

1939–1946

We believe that the years between 1939 and 1946 were most significant in the evolution of modern standardization philosophy. In this period all of the best and worst features of national standardization efforts were magnified and highlighted by the demands of war production.

1939 saw the beginning of a recognition by the aircraft manufacturers for standardization of parts, materials, and processes on a national basis. This was the year that marked the establishment of the National Aircraft Standards Committee, bringing together the eastern and western groups, which had functioned rather intermittently on a regional basis for several years previously. It was in this year also that the engine manufacturers began to consolidate their requirements for materials and processes, which were of a slightly different or higher quality than the existing SAE or AISI type materials. This was the beginning of the SAE-AMS activity. The recognition of the need of pooling industry know-how on problems of interchangeability was beginning to permeate the entire field. Then in 1941 at a meeting held in Washington under the sponsorship of the Office of Production Management, the first attempts to organize the aeronautical industry for standardization on a national scale resulted in the allocation of responsibilities between the SAE and the NASC. The SAE was responsible for handling the engine, propeller, and accessory equipment standardization activities and the NASC concentrated on parts and material forms standardization for the airframe companies. Although this assignment of scope and responsibilities gave industry a pattern of operation, it failed to recognize or achieve the full potentialities of integrated military service-industry efforts in the field.

The industry work on standardization followed three approaches, which were:

1. Development of new standards where needed and no previous standard existed.
2. Development of improved standards where the existing military and commercial standards did not agree or were unsuitable. (It was considered that physical interchangeability with military standards should be maintained, wherever possible.)
3. Analysis of and discussion with the military services of new or changed standards proposed by them.

The first two phases were pursued by the SAE Aeronautics Division and its standards committees. The third phase involved technical discussions having a bearing on contractual relations and has been handled directly by the AIA Engine and Propeller Technical Committees.

Clear-cut lines of responsibility and policy governing the interrelation of the military and industrial standards activity had not crystallized and the tendency was one of divergency of ideas and duplication of results. There was a recognition of the need for coordination, as evidenced by the original OPM allocation, but very little success was achieved in establishing a working method of correlation of effort on a national basis.

1947–1949

The three years following World War II were the ones in which the greatest strides were made toward national organization of the industry for aeronautical standardization. Industry found it desirable to re-evaluate standardization from both the commercial and military viewpoint and to reorganize the procedures for handling standardization on an industry-wide basis. It was evident that the military industrial mobilization planning would require a continued high priority on standardization of parts, materials, processes, and all items necessary to the rapid and accelerated expansion of facilities in the time of emergency. Industry recognized the continued need for both company and industry-wide effort in order to maintain positions gained during the war with respect to the use of their equipment in military fields.

The upsurge of national standardization effort during the war years has continued despite reduced aircraft production, primarily because of three factors which were not evident in previous years.

1. The emergence of the aircraft as a principal military weapon.
2. The recognition of the importance of standards in logistics and industrial mobilization planning.
3. The evolution of a philosophy and plan for combining industry and military objectives in standardization.

Standards Are Dynamic

There are many people who consider that once a standard is established, the subject matter from there on can remain static. It is our experience that new applications and new usages almost at once make a standard obsolete. The engineers assigned to the task of promulgating these standards must ever recognize the changing influences which are occurring and must ever be diligent to keep the standards over which they have design authority up to date.

In order to proceed with our present effort and to realize all possible advantages, it appears necessary to maintain and continue over an extended period of time a competent group of engineers selected from the services and industry as a working team to exploit the full field of standardization, and to keep the subject dynamic and ever useful to the designing engineer.

Obstacles in Standards Program

We do not wish to leave the impression that the development of the present procedure and philosophy was accomplished without recognition of existing and probably continuing obstacles. Some of these obstacles are peculiar to the aeronautical field, but others in general are common to our whole industrial endeavor.

For example, the problem of too much or premature standardization is normally a danger in any standardization effort. We learned from the Germans in 1943-1945 the catastrophe of overstand-

ardization, which stifled development and rendered obsolete equipment, only to lose a war. Premature standardization will inevitably hamstring development because it subordinates the incentive for product improvement. The adherence by some cities to antiquated building code standards is one example of this in another field, and, although our industry is considerably younger than the building trade, we can see similar dangers in attempting to rush into extensive standardization of individual parts before they have actually been rendered standard by usage.

Another great danger peculiar to the aeronautical field by the very nature of its business is the problem of Government regulation or control, versus assistance or direction of national standards activity. We all recognize the need for standards to be voluntarily determined and adopted by industry. If they become restrictive, mandatory procedures, they also become controls on an industry that needs freedom of action if it is to continue technological advances and prepare for mass production in emergency periods. Standards of all types must continue as self-imposed codes of action which are elastic and free to change as the industry itself moves ahead. We believe that the Government, both military and civilian agencies, recognizes this danger, and that our present teamwork philosophy, which reflects distinct responsibilities of each group, will not be improperly used as a regulatory or controlling function of Government. It is certainly the industry's responsibility to maintain active and enlightened leadership to forestall the need of Government assuming proprietary interests in standardization.

Another source of danger at both the company and the national level is the dilution of standardization effort through concentration of standards specialists on detail problems. There is a tendency in the industry and in the Government to maintain standards specialists whose principal aim in life is to achieve standardization of some type at any cost in their particular line of endeavor. It is believed necessary that personnel working on standardization should not be confined in their activities to such an extent that they lose sight of proper balance between broad standardization and design limitation on the product. For example, the standards engineer in the average areonautical company should certainly have responsibilities beyond a pure company or national standardization activity in order that he can properly evaluate the results and effects of his efforts. Likewise, in Government, the standards engineer should not allow his zeal for standardization to obscure his sensitivity to the possible improvement of performance and operational efficiency of new equipment.

The problem of cost of aeronautical standardization will, in one form or another continue to be an obstacle in the field. Costs of company and military support of a standards program are questions which plague us like taxes at least once a year. It is heartening to find that, in this peacetime period of relatively low production, there is continued industrial and Government support of the program despite the extensive costs involved.

The military recognition of the need for standardization as a part of mobilization planning has been a major factor in continued financial support of an active industrial program. The increasing recognition by industrial leaders of the effectiveness of standardization as a management implement has enhanced the security of this function in the company budgetary planning.

Throughout the history of aeronautical standardization, it has been evident that aircraft equipment in general required certain strength or quality characteristics in parts and processes which might not lend themselves to economical standardization in other fields. For instance, the type of internal wrenching bolt used by the aircraft manufacturer, or the type of high-strength rivet, is peculiar to the construction and operation of aircraft and of considerably higher quality than would be necessary for a ground vehicle. There are also different levels of strength requirements within the industry itself as between the applications of the airframe and the applications of the propulsion and accessory units. With the great emphasis on unification of military standards, problems will continue to arise in attempting to standardize aeronautical quality material for use by all the services and the consumers. While it is true that comprehensive standardization will achieve greater sources of supply by virtue of greater usage, the peril of this procedure in an emergency, when materials become critical, is one to be reckoned with at the time a standard is selected. If the standard represents the minimum quality for aircraft use, but perhaps a higher quality than is required for ground or water vehicle usage, any reduction in availability occasioned by an emergency will affect aeronautical production to a much greater extent than the other fields mentioned. The question, therefore, becomes one of whether comprehensive standardization is protection or possible peril in an emergency.

Some additional obstacles which bear mention are those concerned with the legality of standardization teamwork, particularly in the field of proprietary design articles. The theory that any standardization activity must be free from an agreement to build or not to build, to use or not to use, is not questioned. The procedures and policies adopted in the aeronautical field involve no agreement to limit a justifiable choice on the part of purchasers. But in the rapidly advancing field of turbine engine design, for example, there is a real need for standardization of parts and materials, many of which may involve patented features. The legal problems, therefore, are concerned principally with a matter of whether the Government can or cannot adopt standards on items which contain proprietary design features and whether industry may or may not participate in the development of such standards. There is an additional question regarding legal status of Government representation on industrial or technical society committees working in the standardization field. We believe that the present organization and operating procedures for aeronautical industry standardization minimize the potential obstacles of this question. The real solution to these problems, however, may lie only in the ultimate overhauling of our legal machinery.

Paper on which this abridgment is based is available in full in multilithographed form from SAE Special Publications Department. Price 25¢ to members, 50¢ to nonmembers.

U. S. Resources Assure Endless Fuel Supply

Based on paper by

L. L. WITHROW

Research Laboratories Division,
General Motors Corp.

THERE are enough known petroleum reserves to provide gasoline for another 12 years at present production rates. But if the past is any indication, new reserve discoveries will keep pace with increasing production rates for a long time to come. Even if crude oil should be dissipated, extensive mineral fuel reserves—shale and coal—offer an almost limitless source of reasonably-priced gasoline.

Ever since 1913 there have been periodic scares of oil shortages. Gasless Sundays in 1918 and predictions of return to horse transportation as late as 1920 are but a few of indications of fears that oil wells would dry up. But the facts have proved otherwise.

As Fig. 1 shows, current known reserves are greater than ever before. And despite the expanded production from 1920 to 1948, ratio of production to known reserves has remained about the same. In 1920, there were 13.5 bbl of crude oil known to exist in the ground for every barrel produced; in 1949—despite a more than fourfold increase in production over 1920—the ratio was 13.5 to 1.

Through the years the ratio of known reserves of petroleum to that produced has been at a level of 13 to 1. Thus at present we have enough crude oil in the ground to last for the next 12 years. We don't know how much more we'll find. That's the ignorance factor.

But suppose additional pools of crude oil no longer can be found in the ground. What then? We can turn to our huge mineral fuel reserves. See Fig. 2.

Shale oil offers 70 billion tons of fuel. In one Colorado range alone, estimates the Bureau of Mines, there are over 200,000,000,000 barrels of recoverable oil. That's over eight times the amount of oil produced in the whole world since Drake drilled the first oil well in Pennsylvania in 1859.

A 1949 Bureau of Mines report says that refined products—mainly diesel oil and jet engine fuel—can now be produced from oil shale at about 7.3¢ per gal. Adding to this a 6% profit on unamortized capital and a 40% income tax, wholesale price for producing material would be 9¢ per gal at Rifle, Colo. This compares with 9.6¢ per gal for jet fuel from petroleum at Houston, Texas, March 15, 1950.

We also have two thousand billion tons of coal. A recent report from the Secretary of the Interior estimates that refined products from coal hydrogenation would cost 14.5¢ per gal, including profit and income tax. Main product would be high octane gasoline. Price for 91-98 aviation gasoline is 15.5¢ per gal from petroleum at Houston, Texas.

There may be some question at present about 14.5¢ per gal gasoline by coal hydrogenation. But our known coal reserves retain at least several hundred years' supply of liquid fuel energy, and at a price that compares favorably with petroleum fuel. (Paper "Trends in Fuels and Fuel Technology," was presented at SAE Mid-Michigan Section, March 27, 1950. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members; 50¢ to nonmembers.)

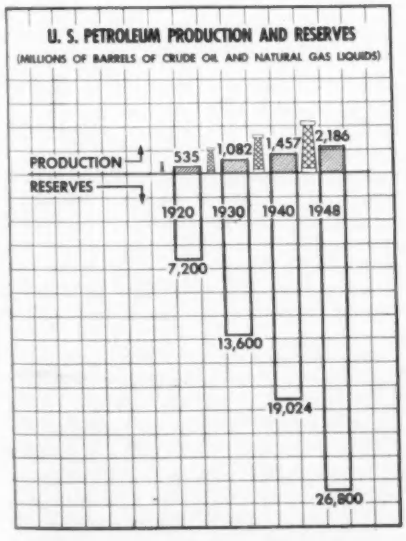

Fig. 1—Over the years, discovery of new oil reserves has kept pace with growth in production. A ratio of reserves to production of about 13 to 1 has been maintained

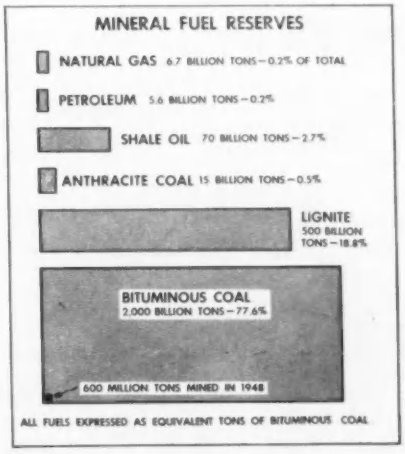
MINERAL FUEL RESERVES
NATURAL GAS 6.7 BILLION TONS—0.2% OF TOTAL
PETROLEUM 5.6 BILLION TONS—0.2%
SHALE OIL 70 BILLION TONS—2.7%
ANTHRACITE COAL 15 BILLION TONS—0.5%
LIGNITE 500 BILLION TONS—18.8%
BITUMINOUS COAL 2,000 BILLION TONS—77.6%
600 MILLION TONS MINED IN 1948
ALL FUELS EXPRESSED AS EQUIVALENT TONS OF BITUMINOUS COAL

Fig. 2—It is estimated that we have enough bituminous coal to supply our needs, at present consumption rate, for over 1000 years. This coal can be converted into several hundred years of liquid fuel supply

Frequent Oil Change Shown Best by Test

Based on paper by

WILLIAM A. HOWE,
JAMES F. DRAKE, JR.,
and H. H. DONALDSON

Gulf Oil Corp.

EXTENDING motor oil change periods beyond 1000-mile intervals allows the oil to become loaded with contaminants and actually accelerates true oil consumption. These facts came to light in a field test of three passenger car groups—one drained after 1000 miles, the second after 2500 miles, and the third after 5000 miles.

Crankcase oil in these cars, operated from 10,000 to 20,000 miles in the test program, became contaminated at an accelerated rate. Lengthening the oil drain interval from 1000 miles produced the following increase in quantity of contaminants:

- 68.3% more carbon and fuel soot,
- 56.4% more oil soluble oxidized fuel and oil products, and
- 55.6% more metals, abrasives, and road dirt.

The increase in contaminants when draining oil at 5000 miles as compared to the 1000-mile drain was found to be:

- 148% more carbon and fuel soot,
- 174% more soluble oxidized fuel and oil products, and
- 114% more metals, abrasives, and road dirt.

Analyses of used oil from field and laboratory tests show the oil soluble oxidized fuel and oil products to be one of the chief causes of oil consumption. They tend to produce engine deposits. These products form varnish and act as a binder to hold carbon and fuel soot on the oil screen and in oil rings, plugging both.

Contaminants Accelerate Wear

The big increase in metal, abrasive, and road dirt accumulation when extending oil drain interval certainly affects engine wear. Oils drained after 2500 and 5000-mile intervals contained as much as 1 lb of contaminants. Average amount of contaminants circulating in engines on the 1000-mile period is only slightly over 1 oz.

The 1000-mile drain period also shows up to advantage in these tests as

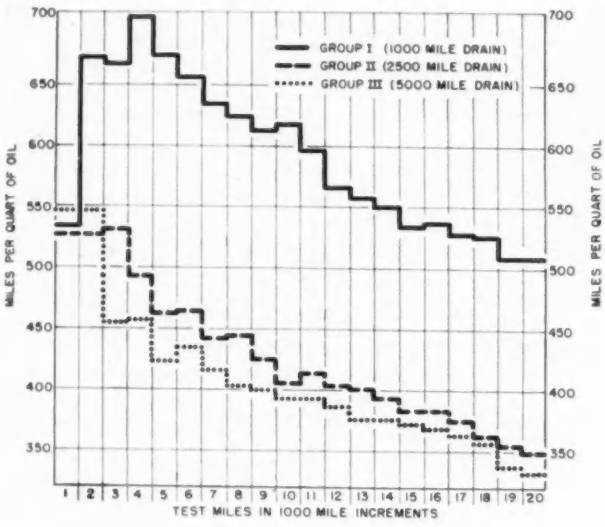
GROUP I (1000 MILE DRAIN)
GROUP II (2500 MILE DRAIN)
GROUP III (5000 MILE DRAIN)
MILES PER QUART OF OIL
TEST MILES IN 1000 MILE INCREMENTS

Fig. 1—Accumulated true oil mileage for three groups of passenger cars in a field test program to study the effects of extending oil drain periods. Oil mileage shown during the last 1000 miles for each group represents the average oil mileage for the entire 20,000 miles of the test

to true oil mileage. Fig. 1 charts true oil mileage for the average vehicle in each of the three groups. Immediate effect of oil drain intervals becomes apparent during the second 1000 miles of test. At the end of 20,000 miles, Group 1 showed tremendously higher average oil mileage than the Groups on the 2500 and 5000-mile drains.

Frequency of oil change plays a big part in true oil consumption. Fact that oil mileage increase immediately after an oil change becomes progressively smaller with each subsequent oil change indicates one of two things. Either engine deposits have accumulated to the point where oil consumption is at its maximum, or it's rapidly approaching its maximum.

Fresh new oil gives much higher mileage than oil used for an extended period. For example, a car on a 2500-mile drain period can get about 100% greater oil mileage during the first 1000 miles of the 2500 than the average mileage for the actual period. In one case, the vehicle averaged 641 miles per qt for the first 1000 miles on fresh oil, but only 346 miles per qt for the entire 2500 miles.

With regard to lube oil costs, there is a saving in extending oil drain interval, but at the risk of higher engine overhaul costs. Only 29¢ per month is saved during the last 5000 miles of the test when following a 2500-mile oil drain as compared to a 1000-mile drain. A 5000-mile drain saves 53¢ monthly.

Considering the quantity of engine deposits and higher oil consumptions on extended drain intervals, the car owner might require a re-ring job at about 20,000 miles. Such a job on the Plymouth, Chevrolet, and Ford averages about $45 to $50. This amounts to about $25 per year, assuming 20,000 miles of operation in two years. Thus engine overhaul costs might wipe out any savings in oil purchases by extending oil drain intervals.

When 30,000 test miles have been completed on each of the test vehicles, more detailed information will be presented as well as a study on the effect on engine wear and related mechanical problems. (Paper "Effect of Oil Change Practice on Engine Condition," was presented at SAE Metropolitan Section, April 6, 1950.)

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6 Questions Answered On

What's Ahead for Airlines On Jet Engine Maintenance?

Excerpts from paper in which **J. G. BORGER asks the questions. . . . Pan American World Airways, Inc.**

R. B. ROGERS answers them. . . . Aviation Gas Turbine Division, Westinghouse Electric Corp.

1. Does high temperature have drastic effect on life of gas turbine parts and is this not the factor that will control overhaul period and service life?

Yes, there is a very definite correlation between maximum total temperature-time and engine life. Happily, however, steady state operation, as at cruise power, is not a serious source of limitation, since the creep characteristics of available turbine blade materials are very favorable.

Only under temperature conditions producing a stage approaching plasticity or rapid oxidation of the metal does life seriously suffer. A bad start or an excessively long exposure to take-off power can each do more damage than relatively many hours of operation at cruise or even normal rated power. Anticipated use of take-off power at 2%—one fifth of the amount of **recorded** military usage of maximum power—should favor engine life very significantly in commercial use.

2. What kind of line service is to be expected for jet engines? Are any other services to be conducted or parts to be replaced between periodic overhauls?

Main problem I foresee in line service during early commercial operation would be possible minor adjustment to control devices for optimum operating ease. I feel, however, that these elements will have been developed to a relatively trouble-free state before jets will be expected to handle scheduled operations.

One consideration which will probably figure in line maintenance is flow-path cleaning, especially in the axial engine. It is quite possible that cleaning will not actually be a problem in commercial service. But if it is, methods will probably be available such that some injection device can be used during ground checks to furnish solvent or abrasive or other cleaning agent to the engine inlet.

Continued on Page 94

SAE National Aeronautic Meeting and Aircraft Engineering Display

September 28-30, Hotel Biltmore, Los Angeles

THURSDAY, Sept. 28

10:00 a.m.

Welcome to Los Angeles
—R. C. STUNKEL, General Chairman of Meeting,
JEROME LEDERER, Chairman

Safety in Performance Operating Rules
—R. B. MALOY, Civil Aeronautics Administration

Research and Development to Promote Safety in Aviation
—T. P. WRIGHT, Cornell University
(Sponsored by Air Transport Activity)

2:00 p.m.

J. E. DeREMER, Chairman

Development of the Anti-Icing System for the J47 Gas Turbine
—N. F. FRISCHHERTZ and B. E. MORRELL, General Electric Co.

Gas Turbine Anti-Icing Tests at Mt. Washington, New Hampshire
—P. M. BARTLETT, Bureau of Aeronautics, and T. A. DICKEY, Naval Air Material Center
(Sponsored by Aircraft Powerplant Activity)

8:00 p.m.

DONALD DOUGLAS, JR., Chairman

Why Patents?
—W. R. LANE, Patent Counsel, North American Aviation, Inc.

Factory Personnel Problems (Human Factors for Maximum Producibility)
—L. O. STOCKFORD and K. R. KUNZE, Lockheed Aircraft Corp.
(Sponsored by Aircraft Activity)

Friday, Sept. 29

10:00 a.m.

J. W. YOUNG, Chairman

Comparison of Turbine-Propeller Engines with Various Cycle Arrangements for Subsonic Flight Speeds
—T. F. NAGEY, National Advisory Committee for Aeronautics

Design and Operation of Gas Turbine Propellers
—R. C. TRESEDER and D. D. BOWE, Aeroproducts Division, General Motors Corp.

Turboprop Installation Problems
—F. H. SHARP, Consolidated Vultee Aircraft Corp.
(Sponsored by Aircraft Powerplant Activity)

2:00 p.m.

W. W. DAVIES, Chairman

Air Transportation and What Is the Technical Future
—K. R. FERGUSON, Vice President, Northwest Airlines, Inc.
—E. C. WELLS, Vice President, Boeing Airplane Co.
(Sponsored by all three Aeronautical Activities)

8:00 p.m.

A. E. RAYMOND, Chairman

Air Transportation and What Is the General Future
—F. B. LEE, Deputy Administrator for Program Planning, Civil Aeronautics Administration
(Sponsored by all three Aeronautical Activities)

Saturday, Sept. 30

10:00 a.m.

REAR ADMIRAL A. C. MILES, Chairman

Industrial Mobilization in the Aircraft Industry
—BRIGADIER-GEN. A. H. JOHNSON, Chief, Industrial Planning Division, Air Materiel Command

Arnold Engineering Development Center
—MAJOR-GEN. F. O. CARROLL, USAF, Commanding General, Air Engineering Development Division
(Sponsored by Aircraft Activity)

BANQUET AND GRAND BALL

7:30 p.m., Saturday, Sept. 30
Grand Ballroom, The Biltmore Hotel
Los Angeles

Ordnance Wants Reserve Officers for Proving Grounds, Arsenals

The expanding activities of the Ordnance Department require additional military personnel for assignment to various proving grounds and arsenals.

As the membership of the Society of Automotive Engineers contains many technicians and engineers interested in military transport and combat vehicles, it has been suggested that such members, holding commissions in the Officer Reserve Corps, be advised through the offices of the Society of the needs of this Department. The immediate requirements are for officers in the grades of captain and lieutenant.

Ordnance Reserve Officers interested in duties involving design, development, proving ground testing (engineering), procurement or production of tanks and trucks, should communicate with Office, Chief of Ordnance, Personnel and Training Division, Washington 25, D. C.

SAE National Transportation Meeting Hotel Statler, New York City October 16-18

MONDAY, Oct. 16

10:00 a.m.

H. O. MATHEWS, Chairman

Why 18,000 lbs? Axle Load Effect on Highway Design and Operation
—H. S. FAIRBANK, U. S. Bureau of Public Roads
(Sponsored by Transportation & Maintenance Activity)

2:00 p.m.

F. B. LAUTZENHISER, Chairman

Symposium on Automotive Traffic Noise:
Report of Automotive Traffic Noise Subcommittee
—PAUL HUBER, Fram Corp.
Why Not Quiet Those Trucks
—E. J. ABBOTT, Physicists Research Co.
(Sponsored by Truck and Bus Activity)

8:00 p.m.

E. J. GAY, Chairman

Automotive Transportation in Saudi Arabia
—R. C. KERR, Arabian-American Oil Co.
(Sponsored by Transportation and Maintenance and Truck and Bus Activities)

TUESDAY, Oct. 17

9:30 a.m.

W. P. MICHELL, Chairman

Traction and Stability of Front, Rear, and Four-Wheel Drive Trucks
—A. H. EASTON, University of Wisconsin
(Sponsored by Truck and Bus Activity)

2:00 p.m.

M. E. NUTTILA, Chairman

Accessibility for Maintenance
Trucks—H. O. MATHEWS, Standard Brands, Inc.
Buses—RANDOLPH WHITFIELD, Georgia Power Co.
(Sponsored by Transportation & Maintenance Activity)

DINNER

6:30 p.m.

Welcome—E. N. HATCH, Chairman, SAE Metropolitan Section
J. N. BAUMAN, Toastmaster
JAMES C. ZEDER, SAE President
"Power on Wheels for Peace or Victory"
GEN. BREHON B. SOMERVELL
President, Koppers Co., Inc.

WEDNESDAY, Oct. 18

9:30 a.m.

F. K. GLYNN, Chairman

What the Fleet Operator Should Know About Fuels and Lubricants
—G. A. ROUND and W. S. MOUNT, Socony-Vacuum Oil Co., Inc.
(Sponsored by Transportation & Maintenance Activity)

2:00 p.m.

M. C. HORINE, Chairman

Relationship Between Maintenance and Motor Carrier Accidents
—H. H. ALLEN, and LOUIS REZNEK, Section of Safety, Bureau of Motor Carriers
(Sponsored by Truck and Bus Activity)

NATIONAL MEETINGS

MEETING	DATE	HOTEL
TRACTOR	Sept. 12-14	Schroeder Milwaukee, Wis.
AERONAUTIC and AIRCRAFT Engineering Display	Sept. 28-30	Biltmore Los Angeles, Calif.
TRANSPORTATION	Oct. 16-18	Statler, New York City
DIESEL ENGINE	Nov. 2-3	Knickerbocker Chicago, Ill.
FUELS and LUBRICANTS	Nov. 9-10	Mayo Tulsa, Oklahoma
	•	
	1951	
ANNUAL MEETING and Engineering Display	Jan. 8-12	Book-Cadillac, Detroit
PASSENGER CAR, BODY, and MATERIALS	March 6-8	Book-Cadillac, Detroit
AERONAUTIC and AIRCRAFT Engine Display	April 16-18	Statler, New York City
SUMMER	June 3-8	French Lick Springs Hotel, French Lick, Indiana

TECHNICAL COMMITTEE *Progress*

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Diesel Fuel Research Aided by Bomb Tests

A constant-volume reactor or bomb has the ear marks of a valuable tool for fundamental research of diesel fuel combustion behavior. Joint Bureau of Mines and CRC Diesel Fuels Division studies with bomb apparatus, discussed in CRC report,[1] "Constant Volume Combustion of Diesel Fuels," point up the potentialities of this method.

Equipment for this technique includes an externally heated reactor containing pressurized air, which is fitted with a fuel injector, pressure sensing element, and suitable charging controls.

The injection process and combustion pressure response are simultaneously shown on a cathode-ray scope. Time orientation of points on the cathode-ray tube sweep allows calculations in the injection-combustion cycle. Calibration of the pressure sensitive element and amplifying network permit calculation of pressure at any point.

Advantages of the bomb method are simplicity, precision of control and measurement, and the small sample requirement. Big problem, notes the report, is applying data from this relatively static process to performance in a violently dynamic one of an engine.

Tests made with this equipment (detailed in the report) have convinced investigators that the method can yield worthwhile qualitative and quantitative information. For future experimentation, they recommend:

1. Researches to establish fundamental relationships between operating conditions of temperature, pressure, fuel-air ratios, and injection. Aim would be to apply these relationships to fullscale engine performance.
2. Researches on fundamental relationships between size and structure of a hydrocarbon molecule and the combustion process as revealed by the bomb.

[1] Paper based on this report has been presented to the American Petroleum Institute.

The report, CRC-250, has 22 8½ × 11 pages, including 19 illustrations and charts. It is available from the SAE Special Publications Department. Price: $1.00 to members, $2.00 to nonmembers.

Narrower Fan V-Belts Proposed in Two Sizes

FINAL details are being ironed out for a proposed standard for narrow fan V-belts and pulleys in two sizes. A group under the joint SAE-ASTM Technical Committee A on Automotive Rubber is working on this project.

The two new sizes being considered —a 0.380 and a 0.500-in. width—are said to minimize belt "squeal" and give satisfactory belt life. (Narrowest groove size in the present SAE Standard is ⅝ in.)

Fig. 1 gives the general dimensions of the two proposed sizes. The drawing, on which there seems to be general agreement, is just a part of the standard being developed by the Committee. Work is now under way on tolerances and run-out.

E. G Kimmich, Goodyear Tire &

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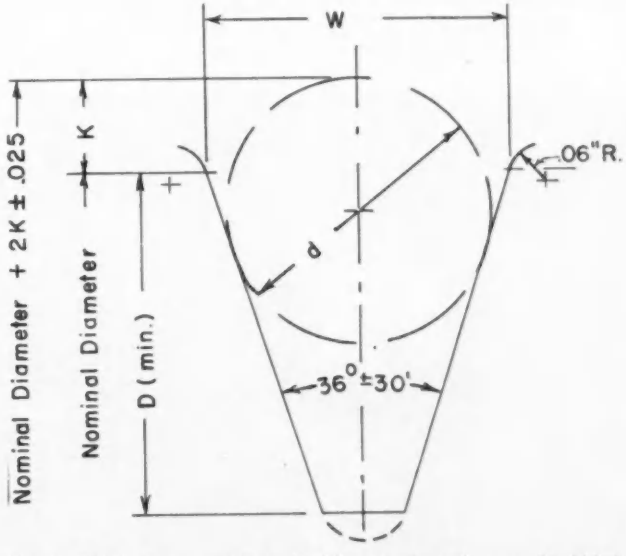


Fig. 1—This is the proposed standard for two sizes of narrow fan V-belts and pulleys, being developed by the joint SAE-ASTM Technical Committee on Automotive Rubber. Dimensions of these sizes are:

W	D (Min.)	d (ball Diam.)	K	2K
0.380	0.430	0.3125	0.077	0.154
0.500	0.562	0.4375	0.157	0.314

SAE AT UNIVERSITY OF

At University of Illinois, the SAE Student Branch was bigger at birth than any other SAE Branch baby in history. And no other Branch has grown faster, nor had broader activity. Reasons: A combination of senior help and student interests that is unusual, if not unique.

Professor W. L. Hull uncovered student enthusiasm about SAE soon after he arrived at Urbana from University of Colorado—where he had guided and advised a successful SAE Student Club. He sent for 50 student applications on May 25, 1948. Soon, the pre-Branch Club was born. Like Aphrodite from the brain of Jove, it sprang into being almost full panoplied. Ten months later, SAE President Stan Sparrow came in person to Urbana to present to Student Chairman James A. Tucker an official Branch charter. Thus, the University of Illinois Group became the first Student Branch to receive its charter directly from the hands of an SAE President.

Seven SAE members on the faculty of University of Illinois provide an understanding climate for the new Branch to flourish in. The seven include Professor Hull (M '36), who is faculty adviser, and young Assistant Instructor Bernard Peskin (J '49), who was the first chairman of the Club two years ago. The other five are: Professor Emeritus J. A. Polson (M '16); Associate Professor J. C. Miles (M '48); Assistant Professor R. C. Juvinall (J '42); Associate Professor E. L. Broghamer (M '49); and Assistant Instructor C. L. Sonnenschein (J '49).

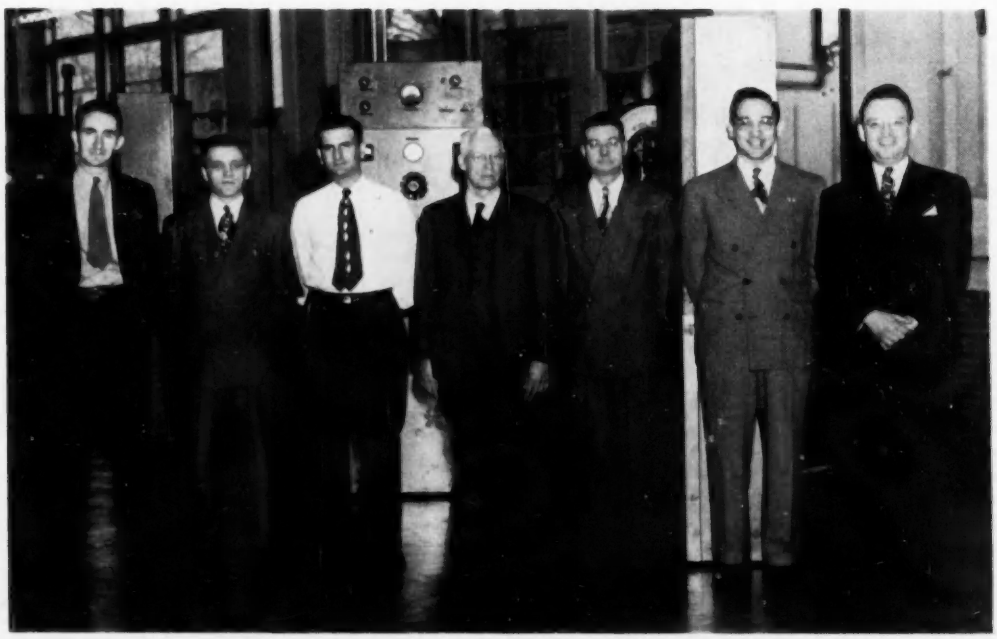
SAE men from the Central Illinois Section who regularly drive 200 miles to be present at Branch meetings—and who helped with the original Club—also are credited by 1949-1950 Student Branch Chairman W. Hopper with a major assist. They helped, he says, "financially and by participation."

And the Branch glows with confidence of continued senior interest and backing as it looks at the nearly 200 names in the SAE Roster of members who are alumni of University of Illinois.

The Branch itself keeps moving with all the aggressiveness and vigor characteristic of its youth. It has 154 members now.

A freshly-equipped internal combustion laboratory in a new $1,798,000 Mechanical Engineering Building has aroused new interests in SAE subjects throughout the period during which the Branch has been going. Professor Hull directs the organization and equipping of this laboratory, which gives it added ties for SAE Branch members. The Branch participates on the campus in the Engineering Council, on which it has two voting members. Through these members it helps control overall engineering campus student affairs and to correlate campus engineering activities.

Speakers at Branch meetings usually bring data and experience direct from industry. On-campus speakers are the exception. Typical of leading engineers who have talked to the Branch at its regular meetings, in addition to SAE Past-President S. W. Sparrow, Studebaker Corp., are: C. N. Bentley, DeLuxe Products Corp.; R. B. Sneed, Ethyl Corp.; Edmond Bisson, Cleveland Laboratories, NACA; W. F. Shurtz, Twin Disc Clutch Co.; Wilbur Shaw, president, Indianapolis Motor Speedway, and many others.



SAE members on the University faculty: Left to right: Prof. J. C. Miles, Prof. E. L. Broghamer, C. L. Sonnenschein, Prof. J. A. Polson, Prof. W. L. Hull, B. A. Peskin, and Prof. R. C. Juvinall

University of Illinois' new one-and-a-half million dollar mechanical engineering building

ILLINOIS

The Branch is active in many campus activities, notably the Engineering Open House which, each spring, aims to bring University of Illinois engineering favorably to the attention of out-of-town guests in general and high-school students in particular.

SAE members who attended University of Illinois include:

George B. Allen (1907-11), Clifford H. Allen (1938-40; 1943-45), Ivan G. Anderson (1921-23), Dan M. Avey (1906-1910), Rufus P. Austin (1921-25), Paul C. Baker (1935-1939), Charles R. Barrick (1930-35), George A. Becker (1946-49), A. C. Bell (1927-31), H. H. Benninger, Jr., (1933-39).

Wilbur W. Betts (1932-35), John R. Boyd (1938-42), E. A. Braker (1922-26), R. K. Braunsdorff (1914-20), C. H. Brown, W. I. Buchanan (1924-29), Waldo Briggs Burnett (1920-23), K. L. Burroughs (1926-30), Raymond H. Bohman (1939-43), Homer W. Butterbaugh (1918-22), Dean C. Broughton (1940-43; 1946-47).

John J. Campbell (1940-43; 1947-49), O. A. Carnahan (1908-10), George R. Caskey (1917-21), Scott Chandler (1922-26), Edgar S. Cheaney (1942-44), Earle Walter Chesnutt (1946-49), Ralph Cookman Chesnutt (1912-14), Glenn Coley (1914-17), Erwin W. Crane (1934-40), John J. Corrigan, Jr. (1946-50).

Milo F. Denick (1913-20), Frank B. Doyle (1915-20), V. L. Durrstein (1927-31), F. E. Edwards, Jr., (1930-38), Joseph Di Vito (1939-43), Alpiner S. Eichman (1938-42), Robert T. Elliott (1913-17), Norman G. Esbrook (1942; 1946-48), G. H. Esch (1930-34), Edwin R. Evans (1903-07).

T. M. Fahnestock (1926-31), Howard Field, Jr., (1913-17), Ernest F. Fiock (1919-26), Warren D. Foltz (1928-32), Stewart E. Gail (1937-41), Robert W. Gaines (1935-39), Charles B. Gale (1924-28), John M. Gerty (1946-47), Leonard B. Gilbert (1922-26), Philip Glick (1919-21).

L. C. Goad (1919-23), F. R. Grant (1926-33), T. K. Greenlee (1924-30), Robert J. Greenshields (1930-32), Gordon C. Gregory (1940-42; 1945-46), George B. Grim (1938-40), Frank A. Grooss (1938-41), William Neal Groves (1945-49), Earle D. Haley, Jr. (1940-41; 1946-48), M. L. Hamilton (1930-32), W. E. Haselwood (1925-29), B. Morris Henderson (1946-49).

Fred C. Heinig (1932-36), Otto R. Hills (1927-31), José M. Homs (1906-10), Vincent H. Hoehn (1928-30), C. F. Hood (1911-15), Wallace Hopper (1945-50), Charles H. Jacobson (1906-10) R. E. Jeffries (1934-38), M. J. Jeswick (1937-41), Carl D. Johnson, Jr. (1939-41; 1944-46).

Russell H. Johnson (1918-22), Blythe R. Jones (1922-26), Arthur W. Kimbell (1909-13), Robert A. Klee (1938-41), Carl G. Kustner (1919-23), E. W. Lager (1916-21), Rudolph Lenich (1946-49), Thomas K. Lewis (1915-16), L. C. Lichty (1914-16), John P. Lichter (1911-13).

C. W. Lincoln (1910-16), Fred R. Lofthouse (1942-45), Thomas M. Logan (1931-35), Edgar Russell Lower, Jr. (1946-49), R. A. MacGregor (1935-38), Earle S. MacPherson (1911-15), Ernest R. Maxfield (1946-49), William E. McCarthy (1944-48), Lloyd A. McCormick (1925-30), George L. N. Meyer (1917-21), Charles M. Middlesworth (1934-41), Ernest R. Maxfield (1946-49).

I. B. Morgan (1917-22), E. F. Nason (1929-32), A. Walter Neumann (1938-42), John Newton (1936-38), Adolph L. Nelson (1911-16), Fred H. Norris, Jr. (1932-34), Evan E. Olmstead (1932-36), Charles M. Ong (1931-32), Kenton C. Opperman (1942-43), Alan E. Park (1939-43), Arthur A. Parquette (1931-37).

J. George Penn (1909-13), Bernard A. Peskin (1946-49), Kenneth R. Peterson (1945-47), Keith L. Pfundstein (1937-40), R. Donald Pinkerton (1928-32), A. T. Pope (1939-43), Robert P. Powers (1933-38), D. C. Prince (1910-13), Robert A. Pritzker (1946-47), Philip R. Proctor (1935-39).

Edwin E. Puls (1920-23), William H. McQuiston (1936-40), Milton R. Rearick (1936-40), M. J. Reed (1913-17), Lawrence I. Reilly (1921-25), Barrett G. Rich (1921-25), David Rinkema (1938-40), Randall Roman (1925-30), Julian G. Ryan (1931-35), Frank Sailer (1914-18), Clarence T. Rasmussen (1930-34).

W. H. Schachenman (1928-32), George A. Schauer, Jr. (1936-40), Lewis F. Scherer (1921-25), F. A. Schick (1932-35), Carl E. Schmitz (1920-23), F. Glen Shoemaker (1909-14), W. C. Schulte (1928-30), Philip A. Sidell (1934-37), S. A. Silbermann (1919-23), Bruce H. Simpson (1946-47), F. J. Schlink (1908-12).

Jacob S. Smith (1936-37), Roger M. Smith (1936-41), Milo W. Snider (1931-35), Samuel L. Sola (1936-41), Carl L. Sonnenschein (1946-48), Paul E. Speiser (1939-42), Julian Lewis Spencer (1927-31), Glen A. Spraker (1912-14), James W. Starrett, Jr. (1931-36).

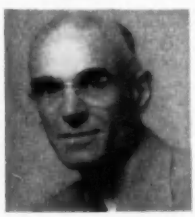
S. J. Steven (1931-33), Ludwig T. Stoyke (1932-38), Robert L. Sutherland (1935-39; 1945-48), E. L. Taudrup (1935-39), Dean G. Thomas (1926-27), Frank A. Tiedge, E. J. Tompkins (1912-14), Robert G. Tuell (1939-43), Robert Twells (1915-20).

Charles D. Walter (1937-40), W. H. Warneke (1926-30), Robert G. Waters (1936-40), John L. Webb (1938-40), Robert F. Weber (1924-29), Fred E. Weick (1919-22), Arthur J. Welch (1924-28), Eugene Philip Welcher (1941-43; 1946-49), V. L. Westberg (1928-30).

Donald H. Westermeier (1940-41), R. C. Williams (1929-32), Grover C. Wilson (1913-17), Robert E. Wilson (1944-48), Ernest M. Woerner (1929-31), J. S. Yule (1929-31; 1932-34), Erwin E. Ziemann (1946-48), Vernon M. Zwicker (1934-39).

CLYDE R. PATON has been appointed director of engineering for Willys-Overland Motors, Inc., Toledo, Ohio. Paton was responsible to a large extent for the development of a number of well-known passenger car designs. In addition to holding various administrative positions at Packard, he also served in executive engineering posts with Studebaker, General Motors and Ford. Paton is a past vice-president of SAE for Passenger Car Activity, has been a member of the SAE Technical Board, and was chairman of the Detroit Section for 1934-'35.

H. R. GIBBONS has been appointed to the position of chief engineer in full charge of product design, research, application and service engineering at the Hyatt Bearings Division of GMC, Harrison, N. J. He has been assistant chief engineer for the past seven years. Prominent in engineering capacities for over 35 years, his wide technical and engineering experience in automotive, tractor and implement and industrial fields ably fits him for his new assignment.



O. W. YOUNG has been named technical assistant to the office of the general manager at the Hyatt Bearings Division of GMC, Harrison, N. J. Prior to this, he was chief engineer with the same company. Young is one of the pioneers in applying antifriction bearings to farm tractors and originated many advances in overall tractor designs.

PAUL MAURER has accepted a new post as vice-president of National Pneumatic Co., Inc., Boston, Mass. Prior to this, he was vice-president in charge of engineering with Redmond Co., Inc., Owosso, Mich.

JACK P. PEDERSON has been appointed general manager of the Warner Division, Clinton Machine Co., Detroit, Mich. Pederson, although relatively young in years, has had a wealth of business and aviation industry experience. For the past two years, he has been associated with Powell Crosley, Jr. Before that, he was regional manager of the Detroit area for the Scintilla Magneto Division of Bendix Aviation Corp. for six years.

New Ford Directors

D. S. HARDER and HAROLD T. YOUNGREN are two of the five Ford vice-presidents who have been elected directors of the Ford Motor Co., Dearborn, Mich.

HARDER

YOUNGREN

About

SAE PRESIDENT JAMES C. ZEDER, director of engineering and research, Chrysler Corp., has been appointed to the National Inventors Council, of which SAE Past President C. F. Kettering has been chairman since its organization in 1940. The Council serves to bring the technical needs of the federal government to the attention of America's independent inventors.

W. E. BRIECE, formerly division manager of the Pacific Airmotive Corp., Kansas City, Kans., is now president of Diamond T Truck Sales, Kansas City, Mo. Briece has made this change after twenty years in the aviation business. He was chairman of the SAE Kansas City Section (1947-48).

J. HENRY HICKMAN, formerly regional service manager of the Coach Division of GMC, New York, and Pontiac, Mich., is now district representative for that same company in Pontiac.

CAPTAIN RAYMOND W. PECAUT is now chief, automotive section, 8046th ordnance field group, stationed in Yokohama, Japan. Prior to this, he was chief, transport vehicles section, Research and Development Division, in the Pentagon Building, Washington, D. C.

LLOYD L. BOWDEN, a June graduate of Lawrence Institute of Technology, is a service trainee with the Detroit Diesel Division of GMC, Detroit, Mich.

A. VERLE HAPTONSTALL, who graduated in June from Oregon State College, is a junior maintenance engineer with Peter Kiewitt & Son's Construction Co., Omaha, Nebr.

ROBERT C. BIVONA, a graduate of the University of Oklahoma, is a mechanical engineer at the Aberdeen Proving Ground in Maryland.

F. W. MARSCHNER, who retired last June, as administrative assistant with the New Departure Division of General Motors Corp., is now vice-president of J. M. Hickerson, Inc., New York City.

Members

MIGUEL ORDORICA and **GEORGE W. SCHARBACH** have been appointed to new positions on the Willys-Overland engineering staff. Ordorica has been named a special assistant to the chief engineer, to process and expediate military contracts and service complaints and major projects in the chassis, body and experimental divisions. Since 1945 he has been quality engineer, chief engineering inspector and lastly assistant director of research for Willys-Overland. Scharbach, who fills the vacated position of assistant director of research, has been experimental project engineer since he came to Willys in 1946. He attends the Mississippi State College and was graduated from the University of Toledo in mechanical engineering.

DEAN FALES, Massachusetts Institute of Technology, drove the first car, a Jaguar, over New Hampshire's new turnpike at the formal opening of the toll highway on June 24.

STEPHEN JOHNSON, JR., a past vice-president of SAE, has been elected vice-president of the Johnny Appleseed District Chapter of the S.P.E.B.S. Q.S.A. (Society for the Preservation and Encouragement of Barber Shop Quartet Singing in America). Johnson is also chief engineer of Bendix-Westinghouse Automotive Air Brake Co. of Elyria, Ohio.

THOMAS L. JACKSON, formerly truck program planning analyst for the Ford Division of the Ford Motor Co., Dearborn, Mich., is now employed as factory manager for the Streator Coca Cola Bottling Works, Streator, Ill.

FRED H. ESCH has recently accepted a position with The Kellex Corp., Silver Springs, Md. Prior to this, he was doing graduate work at Carnegie Institute of Technology.

WILLIAM B. TILDEN is no longer with The White Motor Co., Houston, Texas, but has returned to his previous position as automotive lubrication engineer with The Texas Co. of that same city.

HAROLD R. HARRIS, now vice-president and general manager of American Overseas Airlines, will become vice-president in charge of Pan American's Atlantic services, with headquarters in New York. A brigadier general in the Air Transport Command during World War II, Harris is a command pilot with 5,500 solo hours. He joined Pan American-Grace Airways in 1929, serving as vice-president and chief operations officer until 1942 when he entered the Air Transport Command. He joined American Overseas Airlines in 1945. He was SAE vice-president representing Air Transportation Activity in 1947.

WILLIAM H. CHAPMAN has been appointed director of engineering to coordinate machine and product design, research and application engineering at the Hyatt Bearings Division of GMC, Harrison, N. J. Chapman joined Hyatt in 1922 as a foreman in charge of race grinding.

THOMAS WOLFE has been elected president of Pacific Airmotive Corp., Burbank, Calif. With over 25 years of aviation and general administrative experience behind him, Wolfe has held a number of important posts. Most recently he was vice-president of Pan American World Airways, where from San Francisco he headed the Pacific-Alaska Division during the period of expansion across the Pacific. Prior to that, he was for many years with Western Airlines as vice-president in charge of traffic.

DOCTOR GEORGE CALINGAERT, associate director of research on manufacturing and chemical products, Ethyl Corp. Research Laboratories, has been appointed professor of chemistry at Hobart and William Smith Colleges, Geneva, N. Y. Holder of ten patents in several fields of chemistry, Dr. Calingaert is the author of over 50 technical publications.

GLENN BAUMHARDT has been named vice-president in charge of engineering for Redmond Co., Inc., Owosso, Mich. He joined Redmond in 1940, and from 1943 to 1948 he was sales manager. He advances to his new position from vice-president in charge of sales-engineering, a laison activity between the sales and engineering departments.

ERWIN RAUSCH has been appointed vice-president in charge of manufacturing of the General Automotive Specialty Co. He has been with the company three years as chief engineer. Before that, Rausch was assistant superintendent of Manne-Knowlton Insulation Co. He served with the Armored Forces in the European theatre during World War II.

JOHN R. GRIFFIN has jointed the technical staff of the Du Pont Petroleum Chemicals Division of E. I. Du Pont de Nemours and Co., Inc., Wilmington, Del., as aviation consultant. He will specialize principally in fuel and lubrication problems in aviation. Griffin is a graduate of the University of California, and holds a master's degree in mechanical engineering. He came to Du Pont from the Sharples Corp., where he was chief engineer of the research laboratory.

CARL VOORHIES has been appointed chief engineer of the Valve Tappet Division, The Chicago Screw Co., Bellwood, Ill. In addition to research and experimental work on Hydraulic Valve Tappets for use in new type high-compression overhead valve engines, he will supervise the activities of a fully equipped laboratory for customer service in the solution of valve lifter and valve gear problems.

VAL C. KLOEPPER has been appointed sales representative for The Timken-Detroit Axle Co. Long associated with the automotive industry, Kloepper's experience dates back to 1913 when he became design engineer for the Dorris Motor Co. Following this, he served in engineering and manufacturing executive capacities prior to entering sales.

E. K. VON BRAND is engaged in the manufacture and introduction of a portable continuous smoke recorder, which he developed at the Socony Vacuum Laboratories during recent years. His business is located in Dobbs Ferry, N. Y. The recorder is applicable to all available smoke sources, particularly internal combustion engines.

TOM COLLINS is now general manager of Holland Page Industries, Dallas, Texas. He is in complete charge of sales service and operation of Kenworth Truck dealership. Prior to this, he was president and general manager of the Tom Collins Mfg. Co., Los Angeles, Calif. He was vice-chairman of SAE Southern California Section in 1949.

JOHN J. O'BLENIS, formerly a designer with the Fairchild Engine and Airplane Corp., Oak Ridge, Tenn., is now a designer draftsman with the Bendix Products Division of Bendix Aviation Corp., South Bend, Ind.

BERNARD FISHER is now employed by the Wright Aeronautical Corp., Wood Ridge, N. J., as a junior engineer.

WILLIAM C. MORGAN has accepted a position with GMC in the Detroit Diesel Engine Division.

S. J. LEE, president of Fleet Management Corp., is the author of the newly-published book "Automotive Transportation in Industry." The book analyzes the various types of fleet operation—salesman ownership, passenger car and truck leasing, and company ownership. Advantages and disadvantages of each are pointed out so that management can decide which would best meet its requirements in terms of lowest cost per mile. Fleet management programs now in use are described. The organization and operation of a fleet also are detailed. Copies of the book are available from Fleet Management Corp., 141 West Jackson Blvd., Chicago, for $5.00 per copy.

RICHARD T. BARBOUR, formerly a student at Northrop Aeronautical Institute, is employed as an engineering draftsman "B" by North American Aviation, Inc., Los Angeles, Calif.

WILSON S. LITZENBERGER is now employed in the Nuclear Energy Propeller Aircraft Division of Fairchild Engine & Airplane Corp., Oak Ridge, Tenn., as senior draftsman. He was formerly a mechanical designer with Singmaster & Breyer, New York, N. Y.

JUDSON D. MUNSELL, JR., is now associated with the Pyramid Oil Co., Benton Harbor, Mich., in the capacity of sales manager. Previously, he was division sales manager with the Kendall Refining Co., Bradford, Pa.

C. M. JESSUP has been appointed general manager of the Bedford Foundry Division of GMC, Bedford, Ind. The Bedford Foundry specializes in accurate non-ferrous castings such as those in some of the torque convertors used by General Motors.

HAROLD G. WARNER, formerly with Vauxhall Motors, Ltd., Bedfordshire, England, is now connected with the Cadillac Motor Car Division of GMC, Detroit, Mich.

CLAUDE M. MURRAY, JR., formerly a chemical engineer in the research and development division of the Anderson-Prichard Oil Corp., Oklahoma City, Okla., is now a chemical engineer presently employed as a technical representative to industry for that same company.

Students Enter Industry

PETER E. VIEMEISTER (Rensselaer Polytechnic Institute '50) to Grumman Aircraft Engineering Corp., N. Y.

PAUL H. KLEINMAN (University of Virginia '50) to Ternstedt Div., GMC, Mich.

ROBERT CHAPMAN JR. (Chrysler Institute '50) to Chrysler Corp., Mich.

WILLIAM A. EDGAR (Southern Methodist University '50) to Griffin Mfg. Co., Texas

DONALD E. GREENLAND (Purdue University '50) to Delco Remy Div., GMC, Ind.

CHARLES L. ANDERSON JR. (Purdue University '50) to Kingston Products Corp., Ind.

ERNEST E. PIERCE (Case Institute of Technology '50) to Acme Aluminum Alloys, Inc., Ohio

DONALD K. CLARK (Oklahoma A & M '50) to Shell Oil Co., Okla.

CLARENCE KELLY JR. (Purdue University '50) to Cooper-Bessemer Corp., Ohio

EDWIN M. STARKWEATHER (Northrop Aeronautical Institute '50) to Ralston Industries, Wash.

EDWIN H. SPOEHEL JR. (Massachusetts Institute of Technology '50) to Edwin L. Wiegand Co., Pa.

RENALD HUGHES JONES (Fenn College '50) to Stanley Marks Tractor & Equipment Co., Ohio

HARRY BECK JOHNSON (Bradley University '50) to Alberts Bros. Construction Co., Ill.

ARTHUR GROSS (University of Colorado '50) to General Felt Products Co., Ill.

WILLIAM R. FOLSOM (University of Oklahoma '50) to General Electric Co., Ind.

EMMETT W. COX (The Ohio State University '50) to Link-Belt Co., Ill.

ERNEST A. WEIL (New York University '50) to Teleflex, Inc., Pa.

JOHN MICHAEL WHALEN (University of Illinois '50) to The Buda Co., Ill.

ROBERT SHERMAN (College of the City of New York '50) to Fairchild Engine & Airplane Corp., Tenn.

KENNARD LOWELL WISE (Tri-State College '50) to Tecumseh Products Co., Mich.

RICHARD L. ANDERSON (University of Wisconsin '50) to Corporation of America, Ill.

CLIFFORD D. DENNEY (Indiana Technical College '50) to Evanston Hospital, Ill.

JAMES EWELL ERWIN JR. (Virginia Polytechnic Institute '50) to Paxton Co., Inc., Va.

JOHN L. HILDENBRAND (Purdue University '50) to Goodyear Tire & Rubber Co., Ohio

LAWRENCE E. KNOWLES (University of Wisconsin '50) to Beloit Iron Works, Wis.

ELMER A. KUNNEMANN (University of Oklahoma '50) to Hughes Tool Co., Texas

ALLEN E. LIGHT (Massachusetts Institute of Technology '50) to Continental Aviation & Engineering Corp., Mich.

WALTER H. ROBERTS (Tri-State College '50) to E. I. Du Pont de Nemours & Co., N. C.

WALTON B. SMITH (Rensselaer Polytechnic Institute '50) to Pratt & Whitney Aircraft, Conn.

CHARLES M. SCALES III (Chrysler Institute of Engineering '50) to Chrysler Corp., Mich.

LYNN C. PURSELL JR., (California State Polytechnic College '50) to U. S. Naval Air Missile Test Center, Calif.

DAVID W. PORTER (University of Michigan '50) to General Motors Proving Ground, Mich.

EDWARD L. SMITH (Northrop Aeronautical Institute '50) to Airtoy Co., Calif.

SYDNEY E. HAGERTY (Tri-State College '50) to U. S. Rubber Co., Ind.

ROBERT D. HAYWARD (University of Colorado '50) to B. K. Sweeney Mfg. Co., Colo.

KENNETH W. BERNER (Purdue University '50) to International Harvester Co., Ind.

STEPHEN J. BUCKLEY (University of British Columbia '50) to Massey-Harris Co., Ltd., Canada

DWIGHT E. CLARK JR. (Indiana Technical College '50) to Kennard Corp., Mo.

TRUMAN F. BARBIER JR. (Massachusetts Institute of Technology '50) to Barber and Dulmage, Inc., Mich.

EDGAR R. LOWER JR. (University of Illinois '50) to Chanute Air Force Base, Ill.

GEORGE W. PICKETT (University of Oklahoma '50) to Eastman Oil Well Survey Co., Louisiana

FLOYD CARR JR. (Loyola University '50) to General Motors Corp., Calif.

ROBERT F. MORSE (University of Virginia '50) to E. I. Du Pont de Nemours & Co., Del.

WILLIAM M. WARD (University of Southern California '50) to Concrete Conduit Co., Calif.

JAMES E. CULBERTSON (University of Cincinnati '50) to Manzel Co., N. Y.

EDWIN F. LAWRENCE III (Bradley University '50) to Lawrence Brothers, Inc., Ill.

EDWARD L. BOHN JR. (University of Cincinnati '50) to The Texas Co., Ind.

ALBERT W. RATUSH (Lawrence Institute of Technology '50) to E. W. Bliss Co., Mich.

HARRY L. HAYTER (Lawrence Institute of Technology '50) to Hupp Corp., Mich.

WILLIAM F. JONES (University of Illinois) to Allison Div., GMC, Ind.

CARROLL FREEMAN (The Aeronautical University '50) to ServAero Corp., Fla.

ROBERT J. FITZMYER (Villanova College '50) to Obrien Machinery Co., Pa.

WILLIAM M. BASSETT (University of Illinois '50) to Bell Gossett Co., Ill.

EDWARD A. DRURY (Purdue University '49) to Boeing Airplane Co., Wash.

MALCOLM ROBERT GADDIS (California State Polytechnic College '50) to Southern Pacific Co., Calif.

GEORGE M. TAM (Purdue University '50) to Studebaker Corp., Ind.

FREDRICH G. OBLINGER (Yale University '50) to Pratt & Whitney Aircraft, Conn.

EDWIN B. BOZIAN (Michigan State College '50) to Cadillac Motor Car Division, GMC, Mich.

LOUIS CRESSON (Southern Methodist University '50) to Consolidated Vultee Aircraft Corp., Texas.

ROBERT J. DUBA (Aeronautical University '50) to Lockheed Aircraft Corp., Calif.

MARTIN P. GOLDEN (University of Iowa '50) to General Electric Co., Mass.

ARTHUR P. REEG (Michigan State College '50) to Morton Mfg. Co., Mich.

ROBERT THOMAS HOLMES (University of Southern California '50) to Shell Oil Co., Calif.

ROBERT L. STALLARD, previously a project engineer with Bendix Aviation Corp., Teterboro, N. J., is now a research engineer with North American Aviation, Inc., Downey, Calif.

CLAUDE S. HANSEN, who, prior to this, was connected with the Lubricants Division of Phillips Petroleum Co., Bartlesville, Okla., is now with The Pure Oil Co., Chicago, Ill., as manager of the technical service department.

T. P. WRIGHT, vice-president of research at Cornell University, delivered an address at the commencement exercises of the Polytechnic Institute of Brooklyn on June 14, entitled, "Some Responsibilities of the Scientist and Engineer in the World Today."

KENNETH A. WAIT, who graduated last June from Purdue University, is employed by Bendix Aviation Corp., South Bend, Ind., as a junior engineer.

F. A. JENNINGS, formerly associated with the Martin-Perry Corp., Toledo, Ohio, is now employed as assistant plant engineer by The National Seal Co., Van Wert, Ohio.

DONALD J. STROOP, who, prior to this, was a sales engineer with the Autocar Truck Co., New York, is now employed in a similar capacity by the Whitcomb Locomotive Co. of the same city.

ERNEST LAUDENBACK, a former student at the Academy of Aeronautics, is now employed by Grumman Aircraft Engineering, Bethpage, N. Y., as a plane captain in flight testing.

LEONARD F. BURKE, formerly plant engineer with Motor Products Corp., Detroit, is now employed by the Briggs Mfg. Co., of the same city.

C. E. BANTA of Adams & Westlake Co., Chicago, retired July 1 as manager of the automobile accessory department after 38 years of service to the corporation and its customers. He started his career in the engineering department of Adams & Westlake in 1912, and has been active through the years in company, business, and community affairs.

STANLEY MARKLAND, Leyland Motors, Ltd., Leyland, Lancs., England, now controls all divisions of production, including works engineering, buying, and inspection.

H. A. LIVINGSTONE has sold his interest in the Bailey Motor and Equipment Co., Ocalla, Fla., and his latest project was building the "Congo Belle," a side paddle wheeler for a river excursion boat.

ROBERT S. OGG is now employed by the Lima-Hamilton Corp., Hamilton, Ohio, in the capacity of project engineer. Prior to this, he was educational director with the Diesel Engine Mfrs. Association, Chicago, Ill.

FREDERICK C. REED, formerly design engineer with Consolidated Vultee Corp., Fort Worth, Texas, is now employed by the Boeing Airplane Co., Seattle, Wash., in a similar capacity.

JOHN B. COLE is now president and general manager of Cole, Inc., Fort Walton, Fla. He is engaged in analyzing new locations for possible business ventures.

RICHARD HARWOOD, formerly assistant claims manager with the Buick Motor Division of GMC, Chicago, Ill., has been promoted to claims manager of that same company.

MORRIS J. DUER is connected with the Ingersoll Milling Machine Co., Rockford, Ill., as a designer. He was formerly a senior layout man with the Oldsmobile Division of GMC, Lansing, Mich.

CHESTER C. DEPEW has left ranger Engines Division of Fairchild Engine & Airplane Corp., and is now engaged as an engineering consultant specializing in aircraft reciprocating engines, diesel engines, jet and turbojet engines, and so forth. His business is located in Farmingdale, N. Y.

WALTER WYSS, formerly a project engineer with the Beech Aircraft Corp., Wichita, Kans. is now an engineer with Rhodes Lewis Co., Culver City, Calif.

MARTIN G. GABRIEL is a research engineer in the Research Department of Ford Motor Co., Dearborn, Mich. He had been with the Borg Warner Corp.

WILLIAM A. WILSON has recently joined the Shell Refining & Marketing Co., Ltd., Chester, England, as associate director of research in charge of gasoline development. He had been with the Shell Petroleum Co., London, England.

CHARLES E. WILSON, president of GMC, will be guest of honor at a dinner to be held in the Waldorf-Astoria in New York on October 18, when the members of Automobile Old Timers will celebrate the organization's 11th anniversary.

DAVID FERGUSSON has retired from the position of chief engineer with James Cunningham, Son & Co., Rochester, N. Y. He was with the Cunningham Co. from 1923 till the time of his retirement on June 30. Fergusson writes that he has reached the age of 81, and feels that he should now relieve himself from business responsibilities.

OBITUARIES

MAURICE L. KERR

Maurice L. Kerr passed away on July 8. He had been a chassis engineer with the White Motor Co., Cleveland, Ohio, and had been an SAE member since 1911. He was 62 years old.

CHARLES EUSTACE DWYER

Charles E. Dwyer, a vice-president of the Autocar Truck Co., Ardmore, Pa., died at his home after a 10-month illness. He was 61. He was born in New York and received his early education at schools in Europe. A graduate of Columbia University of 1909 and the university's School of Mines in 1911, he was captain of the soccer football team which won the intercollegiate championship, and also was captain of the fencing team. He had been affiliated with the Autocar Truck Co. for the past 20 years.

During World War I he served as a captain in the Chemical Warfare Division. He was a member of the Baltusrol Country Club, Egypt Mills Fishing Club, Egypt, Pa., Columbia University Club of New York, Germantown, (Pa.) Cricket Club, White Marsh Golf Club, Philadelphia.

FRANK A. BOND

Frank A. Bond, of Pittsburgh, Pa., died of a heart attack on July 3, at his summer home in Erie, Pa. He had been vice-president and secretary of The McKay Co., chain manufacturers, and was prominent in the Chain industry for a great many years. He had been a member of SAE for a quarter of a century, and was also a charter member of the Pittsburgh Section. He was 67 years old.

VERNON C. HOOVER

Vernon C. Hoover, technical advisor, Revere Copper & Brass, Inc., Detroit, Mich., passed away on June 1. He was born in Sunbury, Pa., on July 19, 1904, and attended the University of Michigan and the University of Toledo. He had been with Revere from 1942 until the time of his death.

25 Years Ago

Facts and Opinions from SAE Journal of September, 1925

A maximum limit for beam candlepower, which is not specified in either the present illuminating Engineering Society or SAE specifications, was suggested by J. H. Hunt in discussion of H. M. Crane's paper on head-light illumination at the May Metropolitan Section meeting.

■

"The motorboat industry is on the threshold of a bright future, but should show more interest in standardization," C A. Carlson said at the Annual SAE Motorboat Meeting in New York.

■

A survey of industry use of SAE standard nomenclature for body types is expected to reopen the question of the proper name for the five-passenger two-door type of body. Car makers generally call this type a "coach" or "brougham."

The Passenger Car Body division of the Standards Committee has never specified a name for this type, on the basis that standard nomenclature is intended to apply to basic types of body . . . and that variations of such basic types should include the basic name properly qualified.

On this basis, the so-called coach or brougham should be called a "five-passenger coupe," or a "two-door sedan."

Also, the impression has existed that the five-passenger two-door body, although the cheapest type of closed body to build, would not endure owing to the inconvenience of this arrangement.

■

No matter what the ultimate multi-wheeled motor vehicle may prove to be, A. F. Masury says, one of the immediate stages of development will be along the lines of six-wheel and eight-wheel vehicles.

■

An early power take-off was used on the Pacific Coast in 1904 with a combined harvester and steam tractor. An engine was mounted on the harvester but received its power through a hose from a steam-boiler mounted on the tractor by which the harvester was drawn.—F. N. G. Kranich, Timken Roller Bearing Co. in paper "Power Take-Off for Tractors."

■

Die-casting is a comparatively recent art in its commercial applications. Rapid growth of the automobile industry served as a stimulus for study and develoment of aluminum die-castings, which made their first appearance in 1914. —Marc Stern, Doehler Die Casting Co. in paper, "Die-Castings Made of Non-Ferrous Metals."

■

Question and answer following paper on Engine Governors by E. F. Lowe, general manager, K. P. Products Co.: **Question:** If it is required by the State that trucks be held to a speed of 15 mph, we must cut the engine off below the maximum torque when in first, second, and third speeds. Then, when the truck gets into a hole, it is no good. **Mr. Lowe:** I grant that. Most governors on the market today govern engine speed. . . . The only thing a governor manufacturer can do is to install the governor to work as close to the top of the torque curve as possible. This might bring speed up over legal limits. Governors should be installed to give the truck owner the greatest efficiency from his vehicle.

■

J. J. Cole, president of Cole Motor Car Co. died of a heart attack at his home in Indianapolis on Aug. 5, 1925. He joined SAE in 1911.

■

Advent of the balloon tire has made a tremendous market for shock-absorbers of the one-way type, according to W. B. Groves, Stromberg Motor Devices Co. It also has made necessary, he told the Chicago Section, shock absorbers that do not destroy the purpose of balloon tires and flexible springs by causing excessive restriction over small inequalities in the road.

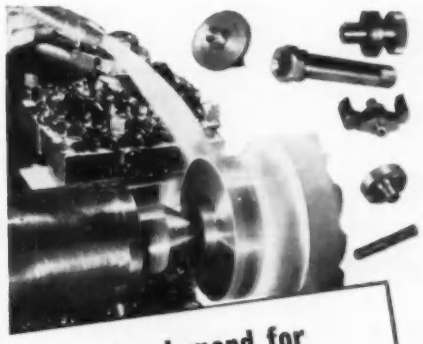
■

Among applicants who were qualified for SAE membership this month was Edsel B. Ford, automobile manufacturer.

■

Personal Notes included:

F. K. Glynn has become associated with the American Telephone & Telegraph Co. Previously he was engineer of motor vehicles for New York Telephone Co. . . . J. H. Hunt, head of electrical research division of GM Research Corp., has been transferred from Dayton to Detroit. . . . Roscoe C. Hoffman, who has been special engineer for Studebaker, has become associated with Eaton Axle & Spring Co., Cleveland.



the demand for
HIGHER PRODUCTION
calls for more attention
to *Cutting Fluids*

★ ***PRODUCTION INCREASED FROM 18 TO 31 PIECES PER HOUR*** machining pipe union from 18-8 stainless steel in single spindle automatic *after* changing over to Stuart's THREDKUT 99.

★ ***SPEEDS, FEEDS INCREASED 50%*** turning, drilling, facing, reaming, tapping forged steel valve bodies (equivalent SAE 1315) on turret lathe after applying Stuart's SOLVOL water soluble cutting fluid concentrate. And, excessive scrap loss due to high finish requirements was eliminated.

★ ***PRODUCTION DOUBLED*** boring 7½" dia. hole through 11" dia. x 30½" long solid forged 5060 steel pump liner through use of Stuart's SPEEDKUT B the multi-purpose cutting fluid.

• These are not isolated examples of how Stuart can help boost production. They are taken from daily field reports. Ask to have a Stuart Representative call. Send for your copy of "CUTTING FLUID FACTS."

D.A. Stuart Oil co.
EST. 1865 LIMITED

2727-51 S. Troy Street, Chicago 23, Ill.

Fan V-Belts

Continued from Page 81

Rubber Co., chairman of the Committee group on V-belts, anticipates early agreement on the two proposed sizes. If and when Technical Committee A approves the new sizes, they will be submitted to the SAE Technical Board for final approval as an SAE Standard.

Proposed New and Revised AMS

The following proposed-new and revised Specifications are being circulated to industry for comment and criticism by the SAE Aeronautical Materials Specifications Division:

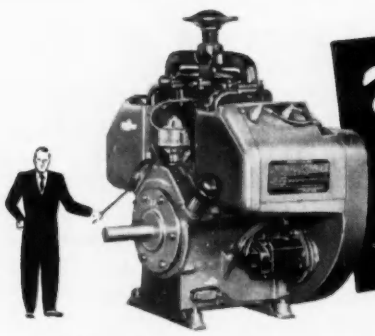
a. The new ones are:

- AMS ——, COMPOUND, AIR FOIL SMOOTHING, HARD
- AMS ——, PROTECTIVE TREATMENT OF ALUMINUM BASE ALLOYS (Alodine Rinse Process)
- AMS 4352, MAGNESIUM ALLOY EXTRUSIONS, ZK60A-T5
- AMS 7470, BOLTS AND SCREWS, STEEL, CORROSION RESISTANT —Heat Treated Roll Threaded

b. The revised ones are:

- AMS 2232A, TOLERANCES, Carbon Steel Sheet and Strip
- AMS 2242A, TOLERANCES, Corrosion and Heat Resistant Sheet, Strip, and Plate
- AMS 5616A, STEEL, CORROSION AND MODERATE HEAT RESISTANT—13Cr—2Ni—3W
- AMS 6281A, STEEL TUBING—SEAMLESS (MECHANICAL), 0.55Ni—0.5Cr—0.2Mo (0.27–0.33C) (SAE 8630)
- AMS 6355D, STEEL SHEET AND STRIP, 0.55Ni—0.5Cr—0.2Mo (0.27–0.33C) (SAE 8630)
- AMS 6359A, STEEL SHEET AND STRIP, 1.8Ni—0.8Cr—0.25Mo (0.38–0.43C) (SAE 4340)
- AMS 6360C, STEEL TUBING, SEAMLESS, 0.95Cr—0.20Mo (0.27–0.33C) (SAE 4130)
- AMS 6365C, STEEL TUBING, SEAMLESS, 0.95Cr—0.2Mo (0.33–0.38C)

Turn to Page 92

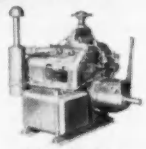


Why WISCONSIN FOUR-CYLINDER Air-Cooled ENGINES ARE ALL V-TYPE

1. V-type design provides a more compact power package for easier, more adaptable installation on original equipment.
2. V-type design means lighter weight, adding to ease of handling and mobility.
3. V-type design provides most efficient air cooling — the air blast travels only half as far as required for a 4-cylinder "straight-in-line" engine.
4. More uniform cooling of V-type engines assures more economical and smoother engine performance; lower maintenance cost; longer engine life.
5. V-type cylinders are cast in pairs, 2 cylinders to a block, thus greatly reducing replacement cost if and when that should be necessary and simplifying servicing.

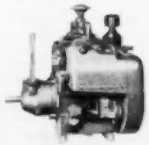
Wisconsin V-type 4-cylinder design is typical of the advanced engineering know-how that goes into all Wisconsin Engines . . . 4-cycle single cylinder, 2-cylinder and 4-cylinder models, in a complete power range from 3 to 30 hp. Write for detailed data.

V VE-4



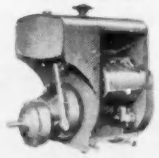
15 to 21.5 hp.

V VF-4



17.5 to 25 hp.

V VP-4



26.8 to 31 hp.

WISCONSIN MOTOR CORPORATION
World's Largest Builders of Heavy-Duty Air-Cooled Engines
MILWAUKEE 46, WISCONSIN

WHAT'S THE BEST WAY TO STRIP PAINT FROM METAL PARTS TOO LARGE TO BE SOAKED IN TANKS?

See Page 3

Oakite's New FREE Booklet on Paint Stripping

answers many questions that will lead you to better stripping procedures. You'll want to read more about:

What's the best way to strip large areas of structural metal where a steam supply is available? *See page 5.*

What is the best method when steam is not available? *See page 7.*

What is the cheapest way to strip metal parts in large volume? *See page 9.*

What are the best ways to prepare stripped surfaces for repainting? *See page 11.*

What strippers are best for removing oil-base paints? . . . Synthetic enamels, alkali-resistant plastics or resin-based paints? . . . Japans, wrinkle finishes, nitrocellulose lacquers, alkyds, phenolics and ureas? *See page 12.*

FREE For a copy of "How to STRIP PAINT" write to Oakite Products, Inc., 50E Thames St., New York 6, N. Y.

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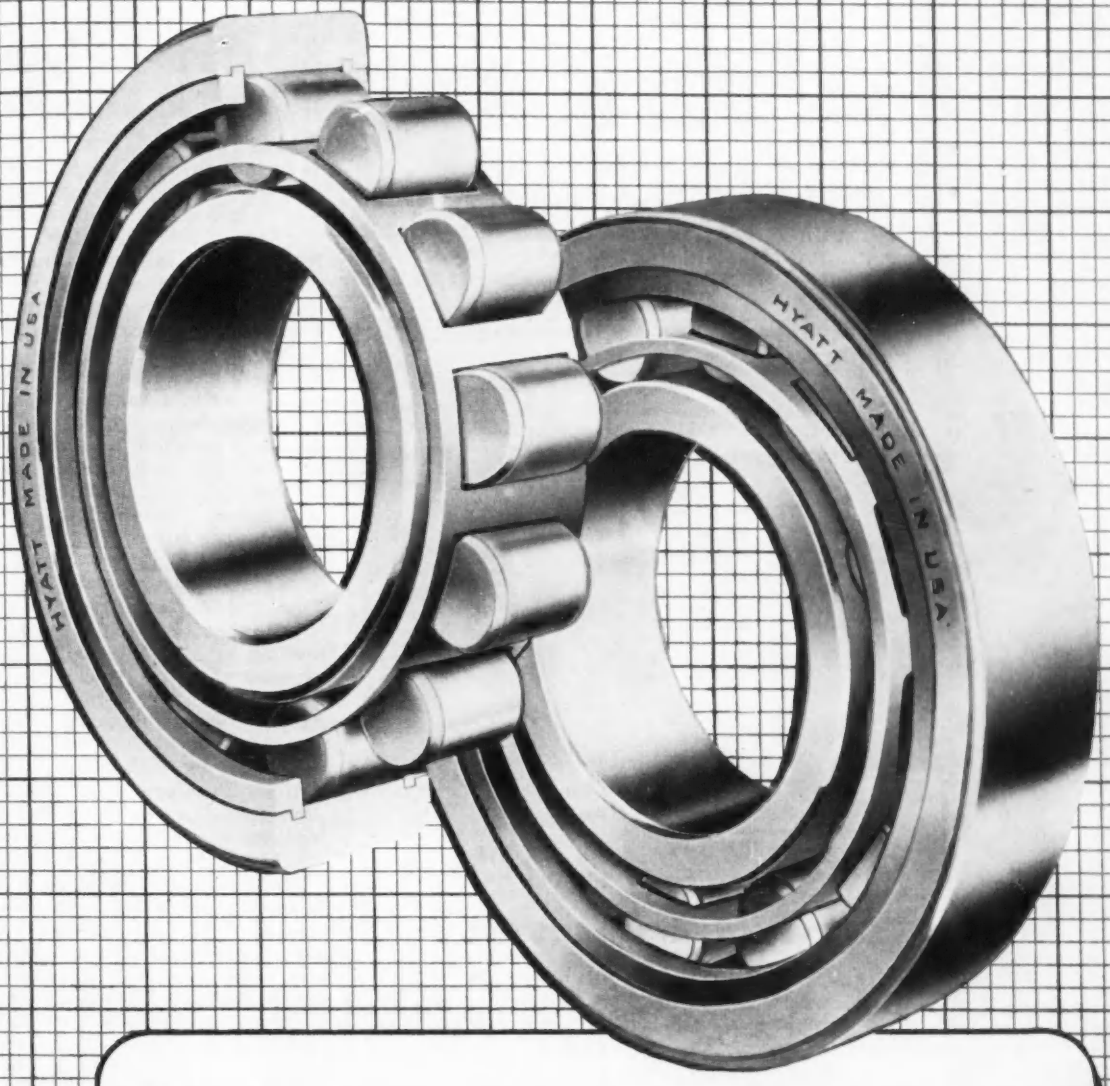

The challenge that keeps Hyatt ahead

Although Hyatt has been supplying roller bearings to the automotive industry since 1892, Hyatt has never rested on its early laurels.

Hyatt has met the challenge of the country's most progressive industry and year after year Hyatt experience, research, testing, and quality production have measured up to the exacting demands of the builders of cars, trucks and buses.

Here at Hyatt are more than four thousand workers doing one thing well—making Hyatt Roller Bearings so good that they are still good after the machines they were built into are out-dated. Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.

HYATT ROLLER BEARINGS

- AMS 6440C, STEEL, 1.45Cr (0.95–1.10C) (SAE 52100)
- AMS 6441B, STEEL TUBING—SEAMLESS (MECHANICAL), 1.45Cr (0.95–1.10C) (SAE 52100)
- AMS 6530C, STEEL TUBING (SEAMLESS), 0.55Ni—0.5Cr—0.2Mo (0.27–0.33C) (SAE 8630)
- AMS 6442A, STEEL, 0.5Cr (0.95–1.10C) (SAE 50100)
- AMS 6455B, STEEL SHEET AND STRIP, 0.95Cr—0.15V (0.48–0.53C) (SAE 5150)
- AMS 6535C, STEEL TUBING (SEAMLESS), 0.55Ni—0.5Cr—0.25Mo (0.33–0.38C) (SAE 8735)
- AMS 6550C, STEEL TUBING (WELDED), 0.55Ni—0.5Cr—0.2Mo (0.27–0.33C) (SAE 8630)

Copies of these proposed specifications are available for review from the SAE Aeronautical Department.

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✓Excellent — material and dimensional consistency assured by permanent mold casting process.
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Write for our new brochure SCIENCE IN THE FOUNDRY. It gives complete information on centrifugally cast cylinder liners and on all other CWC products such as: cast cylinder blocks and heads; cast pistons; cast camshafts; cast crankshafts; cast gears; centrifugally cast Centrifuse brake drums; and a large variety of steel castings.
CAMPBELL, WYANT & CANNON FOUNDRY CO.
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CAMPBELL, WYANT AND CANNON FOUNDRIES
MUSKEGON, MICHIGAN
Henry Street Plant • Sanford Street Plant • Broadway Plant
LANSING, MICHIGAN • Centrifugal Fusing Co.
SOUTH HAVEN, MICHIGAN • National Motor Castings Div.
CWC

Substitute for Columbium Allowed In AMS Stainless

REVISIONS in SAE Aeronautical Materials Specifications, recently approved, permit full or partial substitution of tantalum for columbium in heat and corrosion-resistant steels. These specifications will permit uninterrupted acceleration of aircraft gas turbine and jet engine production, even though columbium demand outstrips supply.

Here is why allowing tantalum as an alternate for columbium is strategically important today:

In 1929 it was discovered that columbium additions of about 1% to 18-8 type steels prevented intergranular corrosion. Columbium (and tantalum too) forms stable carbides. This fixes carbon in such a way to prevent formation of harmful carbides and checks intergranular corrosion.

Second feature of columbium is that it enhances high-temperature characteristics of stainless steels. It imparts superior creep properties.

Columbium ores contain tantalum in varying amounts, which cannot be separated out easily because of the similarity of the metals. Principal source of the ore, a by-product of tin production, has been Nigeria. This ore contains a small amount of tantalum, considered to be insignificant.

To stretch the supply of columbium to meet growing demands, columbium ores rich in tantalum—from the Belgian Congo and South America—are now being used; and imports of them are increasing. Formerly considered unusable, these ores now are being processed to make a ferro-columbium tantalum alloy containing 40% iron, 40% columbium, and 20% tantalum. It's a suitable substitute for ferro-columbium for stabilizing corrosion and heat-resistant steels.

Fortunately, engineering studies revealed that tantalum imparts much the same properties as columbium to corrosion and heat-resistant steels. One part of tantalum can be substituted for one part columbium in high-temperature alloys; but it takes two parts tantalum to one part columbium in corrosion-resistant alloys.

Armed with these data, a group under the SAE Aeronautical Materials Specifications division revised AMS for materials containing columbium. These changes permit use of both columbium and tantalum interchangeably or in combination.

Ten specifications already have been revised. Revision of eight others is under way. The revised AMS are:

1. AMS 5369A—Steel Castings, Sand, Corrosion and Heat Resistant (20Cr—9Ni—1.4Mo—1.4W—Cb—Ti)

2. AMS 5376A—Alloy Castings, Precision Investment, Corrosion and Heat Resistant (Iron Base—20Cr—20Ni—20Co—3Mo—2W—1Cb)

Concluded on Page 94

Great names in the Automotive Industry

DAVID D. BUICK

David D. Buick, Flint, Mich., was a brilliant inventor. His method of applying enamel to cast iron gave America the porcelain-enamel bathtub. Leaving his plumbing supply manufacturing business he developed a valve-in-head engine and in 1902 produced his first automobile.

His Buick Motor Car Co. was backed first by Benjamin and Frank Briscoe, Detroit sheet metal fabricators, and later by a Flint business group, headed by James H. Whiting, wagon manufacturer. When the enterprise lagged, William C. Durant was brought in to head up a reorganization.

Under Durant, the Buick company grew steadily and formed the cornerstone for General Motors, organized in 1908. D. D. Buick stayed with the firm bearing his name until retirement in 1919. He died 10 years later.

(One in a series of sketches about great automotive industry pioneers.)

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MONROE AUTO EQUIPMENT CO.

Monroe, Mich. — World's Largest Maker Of Ride Control Products

Continued from Page 92

3. AMS 5526B—Steel Sheet and Strip, Corrosion and Heat Resistant (20Cr—9Ni—1.4Mo—1.4W—Cb—Ti)

4. AMS 5532B—Alloy Sheet, Corrosion and Heat Resistant (Iron Base—20Cr—20Ni—20Co—3Mo—2W—1Cb)

5. AMS 5533A—Alloy Sheet and Strip, Corrosion and Heat Resistant (Iron Base—20Cr—20Ni—20Co—4Mo—4W—4Cb)

6. AMS 5534A—Alloy Sheet and Strip, Corrosion and Heat Resistant (Cobalt Base—20Cr—20Ni—4Mo—4W—4Cb)

7. AMS 5721A—Steel, Corrosion and Heat Resistant (20Cr—9Ni—1.4Mo—1.4W—Cb—Ti)

8. AMS 5722A—Steel, Corrosion and Heat Resistant (20Cr—9Ni—1.4Mo—1.4W—Cb—Ti)

9. AMS 5765A—Alloy, Corrosion and Heat Resistant (Cobalt Base—20Cr—20Ni—4Mo—4W—4Cb)

10. AMS 5770A—Alloy, Corrosion and Heat Resistant (Iron Base—20Cr—20Ni—20Co—4W—4Mo—4Cb)

AMS undergoing revision as regards substitution of tantalum for columbium are: 5362B, 5363A, 5512B, 5571A, 5575E, 5642B, 5646B, and 7229A.

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Chicago 38, Illinois

Jet Engine Maintenance

Continued from Page 78

Principal line maintenance procedure will consist of periodic dimensional and visual inspection of hot parts. If these inspections do prove necessary, line maintenance practices will include replacement of some elements in the hot end.

3. What should be contemplated in the way of periodic overhaul? What is going to be done at overhaul?

I feel that 500 hr will be the probable initial length of overhaul period. This is roughly double present official military practice.

The overhaul procedures are much the same as those to which you are accustomed. Dismantling and cleaning processes are in the same category as for piston engines. Vapor blast, shell blast, and so forth will be used for cleaning, in addition to solvents. Magnetic particle inspection will serve for many of the durable parts. Fluorescent penetrant procedures are widely used for nonmagnetic blade materials as well as nonferrous parts.

4. What are the relative costs of parts to be replaced both between and at overhauls? How do these compare with parts similarly replaced on reciprocating engines?

I would estimate that part replacement costs between overhauls will be minor. Other than in the case of failure due to defect or abuse, there are no wearing parts which are apt to require replacement between overhauls. Possibly exhaust system parts may be replaced due to distortion or cracking.

In terms of full replacement cost, I would say that turbine engine replacements would be no greater, and probably less, than in piston engines. An occasional accessory change would be necessary in either case, and the values would be fairly parallel.

5. What service and overhaul are required for the systems on gas turbine engines?

Fuel and control systems will need more maintenance than the others. Ignition systems will be relatively durable, with no parts of a really expendable nature. Current-type spark plugs are not frequently replaced.

Lube and scavenge pumps should have reasonably long life, with nothing much necessary at overhaul beyond replacement of seals.

6. What would you estimate for the cost of the first periodic overhaul as a

turn back the pages!

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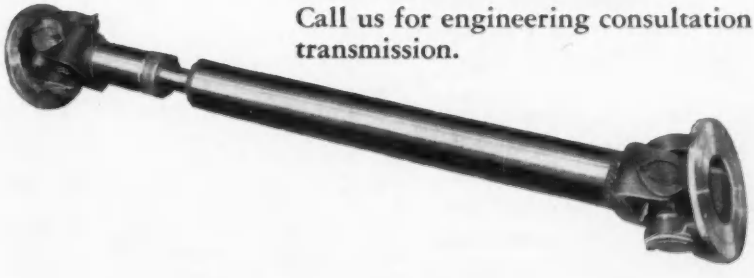

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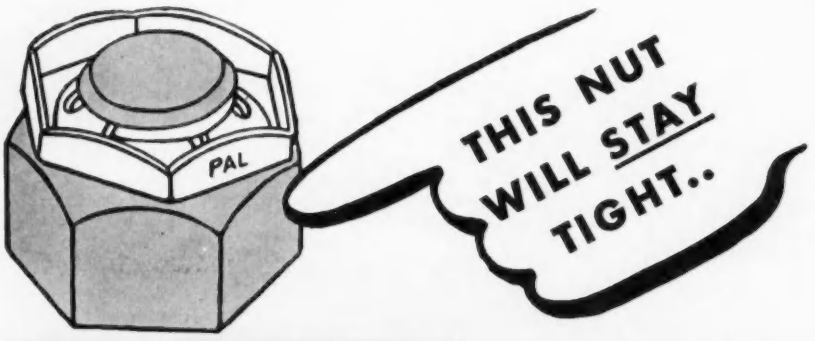
percentage of engine first cost? How about the second and third overhauls?

First period overhaul will probably cost 9 to 11% of first cost. This is based on our general experience with military engines. As to the second and third overhauls, I would not expect cost to be materially greater than that of the initial one.

However, beyond that, it is likely that rework limits will be rapidly reached on some of the major components so that replacement becomes necessary. In this event, the economics of the situation would dictate retirement and cannibalization, and purchase of a new engine rather than continued overhaul of the original one. (Paper "Turbojet Powerplant Maintenance and Overhaul," was presented at SAE National Aeronautic Meeting (Spring), New York, April 18, 1950. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)



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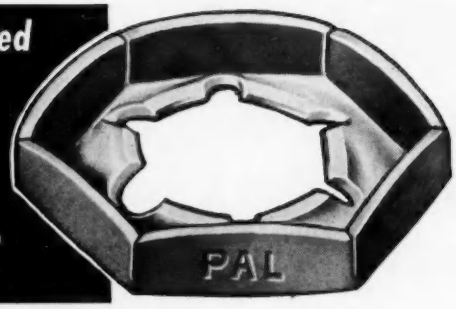

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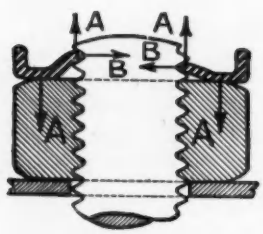

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New Plane Oil System Checks Pressure Drop

Based on paper by

F. E. CARROLL, JR.

Air Materiel Command, U.S.A.F.

(This paper will be printed in full in SAE Quarterly Transactions.)

OIL system failures—due to insufficient oil pressure—at altitudes above 30,000 ft, during World War II, led to Air Materiel Command studies of three aircraft oil systems—the hot tank oil system, the pressurized oil system, and the closed circuit oil system. The closed circuit system proved best.

First system investigated, the hot tank oil system, inserts a boost pump between the oil tank and the engine pump. This system is further modified by removing the oil cooler from the scavenge system, and relocating the cooler between the boost pump and engine pump inlet.

A servo line is provided between the engine pump inlet and the boost pump. This servo line regulates the boost pump discharge pressure to maintain a constant boost at the engine pump inlet. An oil tank diverter valve is installed at the tank inlet. It diverts the return oil flow either to the main tank or through the oil tank hopper, depending on the engine oil temperature.

Second system investigated was a pressurized oil system. The pressurized system simply consists of a pressure relief valve installed in the oil tank vent line of a conventional aircraft oil system. Liberation of entrained air from the oil returned to the tank provides a pressure boost.

With a pressurizing valve, it is necessary to incorporate a negative pressure relief feature. Otherwise, the oil tank may collapse during a dive or other maneuver where the external pressure might exceed the internal tank pressure.

Test results show a pressurizing valve on the engine breather line to be necessary when the oil tank is pressurized. Tests were run with and without a diverter valve in the pressurized and hot tank systems.

Third system investigated was the closed circuit oil system. This design removes the oil tank from the circulatory oil system. An eductor, also known as an ejector or aspirator, is then placed in the system, with the oil tank out line connected to a side passage of the eductor.

For this system to function properly, a static deaerator is inserted between the scavenge pump and oil cooler. A fixed orifice is provided in the deaerator top, from which a vent line is connected to the supply oil or make-up oil tank. The scavenge pump thus acts as

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a boost for the main engine pressure pump.

A potential limitation of the closed circuit system is the high altitude performance of the engine scavenge pumps. However, this limitation is eliminated by the installation of a pressurizing valve in the engine breather line.

The pressurized system is not satisfactory to the Air Force because the self-sealing features of the tank are eliminated. The hot tank system is not desirable because of the power and space requirement of the special boost pump. Results of tests show the closed circuit system is most desirable, both performancewise and installationwise, for use in high altitude operational aircraft.

All the tests, plus additional tests conducted by many other agencies, demonstrate that engine oil pumps are the limiting factor in providing satisfactory high altitude aircraft oil system performance. Therefore, both reciprocating and gas turbine engine manufacturers' should design and provide on their engines a pump which will provide satisfactory performance at an inlet pressure of 2 in. hg absolute, with 10% (by volume) entrained air.

Recent trends indicate that it is highly desirable for the entire oil system to be furnished by the engine manufacturer. (Paper "High Altitude Aircraft Oil Systems," was presented at SAE Annual Meeting, Detroit, Jan. 11, 1950. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

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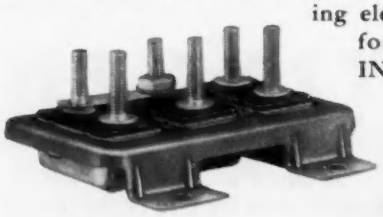

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Two New Types Of Automotive Glass

Based on paper by

ROBERT A. MILLER

Pittsburgh Plate Glass Co.

TEMPERED glass, some five times stronger than annealed glass, and electrically-conductive glass for windshields are two recent automobile glazing developments.

Tempered safety glass consists of a single piece of material, subjected to high heat and then suddenly quenched in a cold air blast. This process places the glass surfaces under high compression and the innermost glass body under high tension. It imparts a strength of four and one-half to five times that of annealed glass.

This greater strength stems from the fact that glass always breaks under tension, never under compressive stress. To rupture a piece of tempered glass, compression on the surface first must be overcome, and then the tensile strength of normal annealed glass exceeded.

Fracturing tempered glass at any point disintegrates the whole piece into tiny fragments resembling rock candy. Disintegration proceeds at the rate of about one mile per second.

In breaking, a piece of tempered glass tends to hold itself in place. Effect is to expand the plate. If not restrained by some framing, fragments tend to scatter in the plane of the glass and may be projected 25 to 30 ft. Fragments do not tend to fly at right angles to the plane of the glass, except under direct impact of a missile.

The broken plate has no residual strength to resist pressures on it, except that from the bridging action of the somewhat interlocking fragments. If broken under sufficient pressure to overcome this interlock, the glass first tends to bulge away from the pressure, then is carried out of the frame.

No fragment without cracks will

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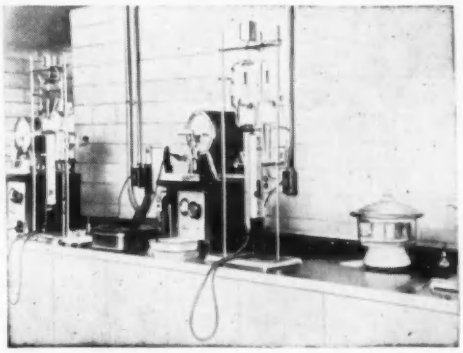
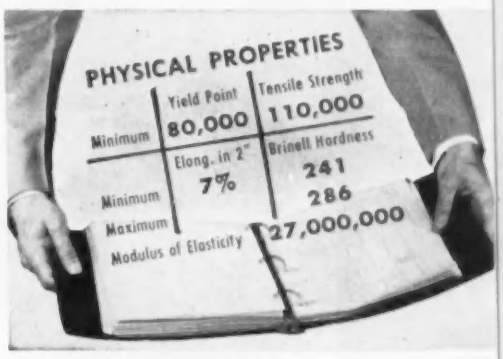
Automotive engineers may not be fully aware of the steadily advancing progress that has been made during the past 15 years in the development of Cast Alloy Steel Crankshafts. To supplement their information on this subject, this, and succeeding Progress Reports will present technical information on the development work that has been done by Auto Specialties Mfg. Co. on Cast Alloy Steel Crankshafts, their growing acceptance, and the accumulating evidence of their unique advantages for mass-produced motor car engines.

Progress report No.1 on the Application of Mass-produced Cast Alloy Steel Crankshafts to the solution of some of today's Engine Production Problems.





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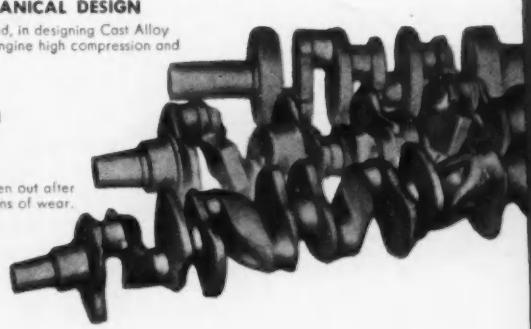

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weigh even as much as 0.15 oz. Thus no serious injury is possible, unless the fragment strikes the eye, or the imposed pressure is of an explosive character.

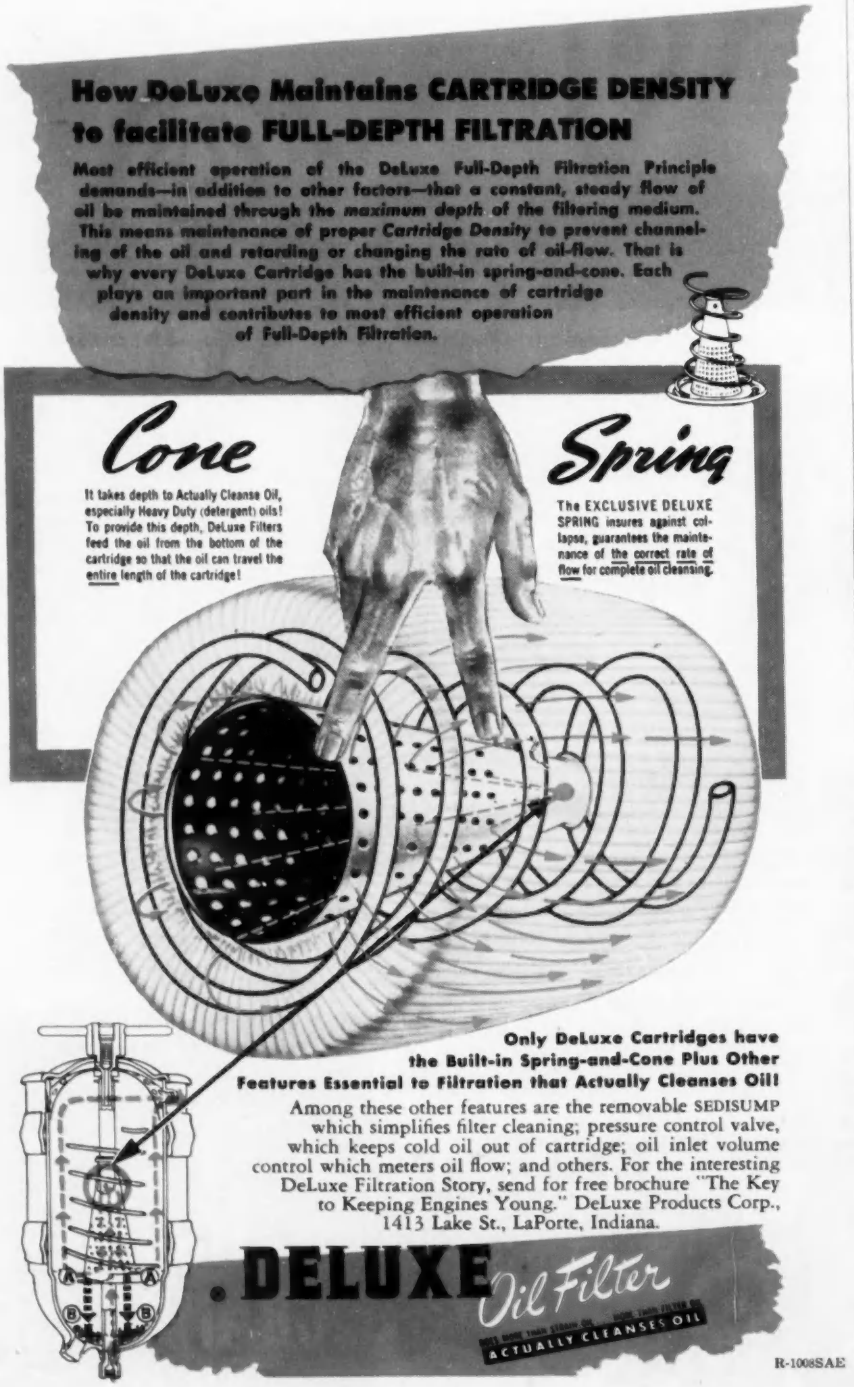
Injury also is possible if some uncovered portion of the body is in the direction of scatter of an unrestrained glass edge, within a few inches of the edge. Tempered glass edges are more susceptible to damage than faces of the plate. They should always be protected against possible impact of a hard metallic object.

Intrinsic strength of tempered glass is perhaps its greatest drawback as a safety glazing material, compared with the less rigid laminated safety glass. This is true in motor vehicle applications where anyone may be thrown head-on against the glass. Laminated safety glass will crack and yield under such impact and reduce the possibility of broken bones. The much more rigid tempered glass will not yield and the full force of the impact must be absorbed by the body and may result in a cracked skull.

Laminated safety glass can be cracked and broken out with the heel of a shoe or even bare hands. It takes a materially harder object to break tempered glass.

Another new product under development, called Nesa, conducts electricity. Its highly transparent coating may be varied through a wide range of conductivity. It can dissipate enough energy to keep a windshield—even a high-speed airplane winshield—completely free of exterior icing or interior fogging. It does so by providing a path for dissipation of small charges of electricity. Nesa also is an effective shield against radiation of short-wave radio frequency energy.

Factors such as high amperage, relatively high voltage, and temperature control have delayed its adaptation to car windshields. But these should be overcome in the not-too-distant future. (Paper "New Developments in Glass," was presented at SAE National Passenger Car, Body, and Production Meeting, Detroit, March 14, 1950. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)


How DeLuxe Maintains CARTRIDGE DENSITY
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Most efficient operation of the DeLuxe Full-Depth Filtration Principle demands—in addition to other factors—that a constant, steady flow of oil be maintained through the maximum depth of the filtering medium. This means maintenance of proper Cartridge Density to prevent channeling of the oil and retarding or changing the rate of oil-flow. That is why every DeLuxe Cartridge has the built-in spring-and-cone. Each plays an important part in the maintenance of cartridge density and contributes to most efficient operation of Full-Depth Filtration.
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The EXCLUSIVE DELUXE SPRING insures against collapse, guarantees the maintenance of the correct rate of flow for complete oil cleansing.
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New Light Thrown On Wright Bros. Story

Based on paper by

M. P. BAKER

Inland Mfg. Division, General Motors Corp.

FROM the construction of their first glider in 1900 to the sale of their airplane to the Army in 1908, the Wright brothers conducted ingenious aeronautical research and applied results with equal engineering skill. Access to Orville Wright's library material has permitted author Baker to piece together the real technical story behind the Wright brothers' contribution to aeronautical engineering.

The paper detailing their experiments, to be printed in full in SAE Quarterly Transactions, unfolds their development progress step-by-step. Much of the information has never before been published.

Baker shows the sound engineering approach to achievement of powered flight. He tells how Orville and Wilbur started with studies on glider flight control in ground experiments. With a full-scale glider, they obtained data disproving the then-published lift characteristics. They also uncovered the dependency for over-all efficiency

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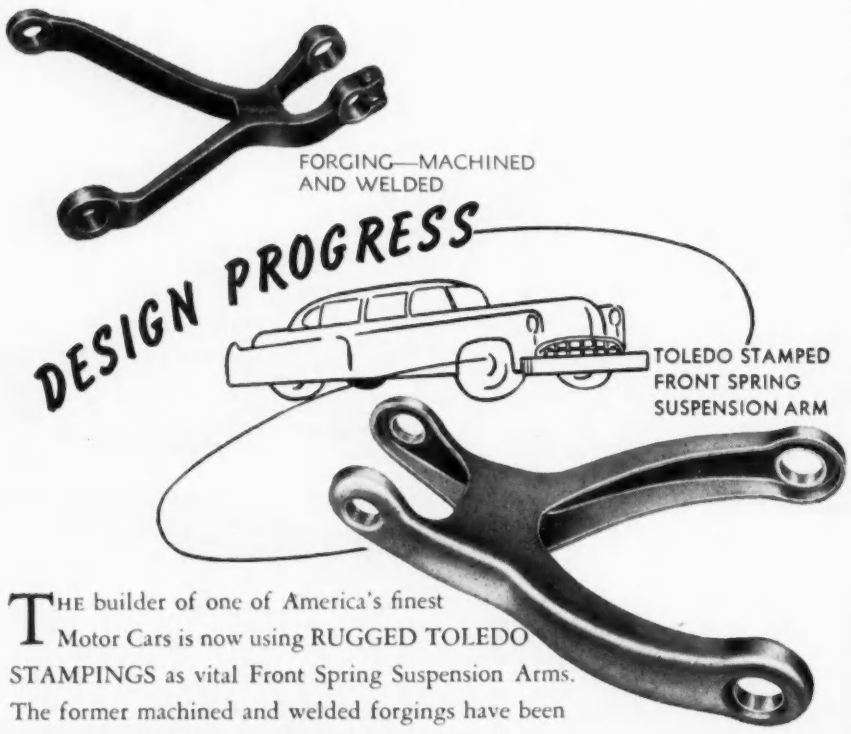
on the L/D relationship (where L is lift and D is drag).

Described in the paper are the crude experimental equipment improvised by the fathers of powered flight, their thinking as revealed in correspondence with aeronautical experts of the day, and their findings that led to a flying machine.

The often over-looked but resourceful engine designs of the Wright brothers also are described. Photographs, reproductions of original data sheets and notes, and engineering drawings of the airplanes add to the historical value of the paper. (Paper "The Wright Brothers as Aeronautical Engineers," was presented at the SAE National Aeronautic Meeting [Spring], New York, April 17, 1950. This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)



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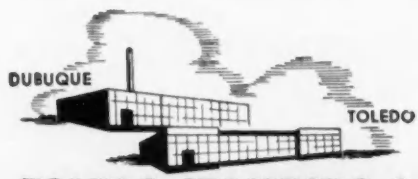

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COMING EVENTS

Cincinnati—Sept. 25

Engineering Society Headquarters, McMillan at Woodburn, Cincinnati, Ohio; dinner 6: 30 p.m. Meeting 8: 00 p.m. Topic: Studebaker Automatic Transmission. Speaker: To be announced.

Detroit—Sept. 15-16-17

Greenbrier Hotel, White Sulphur Springs, W. Va. Semi-technical and social meeting.

Metropolitan—Sept. 13

Brass Rail, 521-5th Ave., N. Y. C.; dinner 6: 30 p.m. High Speed Diesel Engine Design and Development of the Diesel Racing Car—J. C. Miller, Jr., manager, Research and Refinement, Cummins Engine Co., Inc. Cocktail hour 5: 30 p.m.

Milwaukee—Sept. 15

Tripoli Golf Club. SAE Milwaukee Section Annual Golf Tournament 10: 00 a.m. Dinner 6: 30 p.m. Awarding of prizes 8: 00 p.m.

New England—Oct. 3

M. I. T. Graduate House, Cambridge, Mass.; dinner 6:30 p.m. Meeting 7:30 p.m. Preventive Maintenance—Gustav Heiber, vice-president, maintenance of equipment, Boston, Worcester & N. Y. Street Rwy. Co. After coffee speaker—Harry Stanton, automotive editor, Boston Daily Globe. Cocktail hour.

St. Louis—Sept. 12

Crystal City, Mo. Plant Tour of Pittsburgh Plate Glass Co. 2:00 p.m. Inspection Tour (members only). Furnish your own transportation.

SECTION NEWS

Detailed Story of Heavy-Duty Oils

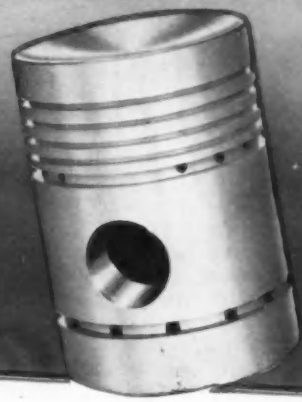
• Central Illinois Section
Harlow Piper, Field Editor

June 12—"Heavy duty oils have improved engine operation and life through the use of additives" said Mr. **J. M. Miller** in his talk "Why Heavy-Duty Oils?" Miller is head of the automotive division sales technical service department of Standard Oil Co. (Indiana.)

In tracing the history of additive

Air Craft

Nelson
Auto-Thermic



Diesel

Trans Slot

U-Slot

Heavy Duty

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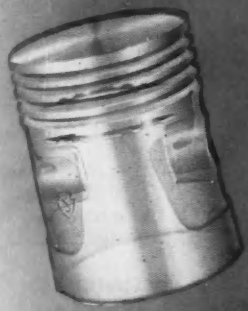


Wing Insert

Two Cycle

Steel Truss

Turbulator head

T-Slot

Trunk Type

STERLING ALUMINUM PRODUCTS INC.

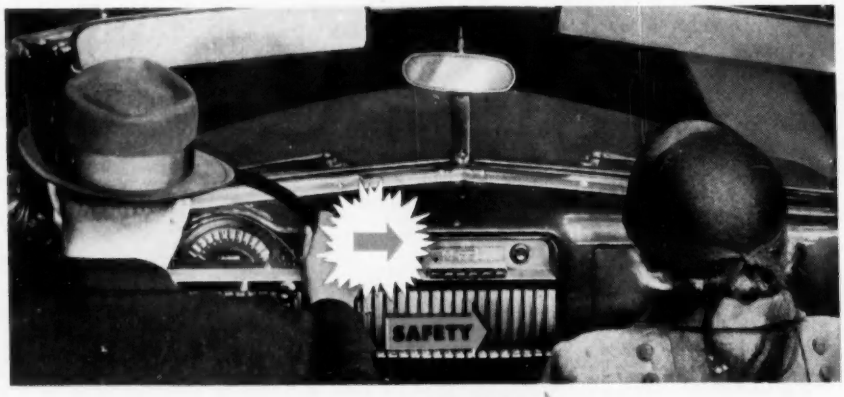
ST. LOUIS, MO.

oils from a British patent issued in 1872, Miller said that the "Caterpillar" diesel, the General Motors 71 diesel, and the Chevrolet engines were historical landmarks in developing Heavy-Duty motor oils. The detergent oils developed for the "Caterpillar" diesel were not satisfactory for Chevrolet heavy-duty service because higher oil temperatures required oxidation inhibitors. The General Motors Series 71 diesel required motor oils resistant to oxidation and having detergent dispersing characteristics. During World War II, much research was done to overcome the effects of high sulphur content which increased the deposit problem.

Today the petroleum industry supplies three general types of crankcase oils. The Regular type contains no additive; Premium contains oxidation and corrosion inhibitors; Heavy-Duty contains corrosion and oxidation inhibitors and a detergent.

Pictures of engine parts were shown illustrating how detergent oils reduce varnish, sludge, corrosion and ring plugging.

The after-dinner speaker was Herman F. Silzer. J. W. Vollentine, staff engineer of Caterpillar Tractor Co., was technical chairman.



SAFETY

SAFETY

SAFETY

SAFETY

Every flash of the Pilot Light Spells—

A perfectly functioning direction signal on an automobile is a tremendous safety factor, both to drivers and pedestrians. But, let a light burn out, or other failure occur unknown to the driver, and safety instantly becomes a hazard.

That is why all automotive signal systems should include TUNG-SOL Flashers. The TUNG-SOL Flasher when properly installed provides the important instrument panel pilot light plus the advantage of instant starting. Its blinking action is assurance that the signal is functioning properly. Its failure to flash means trouble in the system.

Nearly 10,000,000 TUNG-SOL Flashers have been bought since 1939. The TUNG-SOL Flasher is now standard or optional equipment on virtually every American made automobile. It normally lasts for the life of the vehicle, consumes little current and requires no maintenance. *Write for more information.* TUNG-SOL LAMP WORKS INC., Newark 4, N. J. *Sales Offices:* Atlanta, Chicago, Dallas, Denver, Detroit, Los Angeles, Newark.

TUNG-SOL SIGNAL FLASHERS

ALSO AUTO LAMPS, ALL-GLASS SEALED BEAM LAMPS AND ELECTRON TUBES

STUDENT NEWS

Cal-Aero Tech

SAE Student Club members present at the May 27 meeting heard K. F. Finlay talk on "Titanium—Developments and Processes." Finlay brought samples of the wonder metal, and reported that its major asset is its high strength-weight ratio. He said it can replace many heavier structural metal parts, thereby lessening total weight of an airplane as much as 30%. Allowable unit stress of the metal is above 180,000 psi in the cold worked state.

—R. A. Rivero

Aeronautical University

On July 7 William A. Casler, director of student activities, SAE Chicago Section, presented an SAE Charter of Membership to Mr. Finney, chairman of the newest SAE Student Branch.

Guest speakers at the dinner included representatives from United Airlines, who described their duties and some of their problems.

"It is the duty of every aeronautical engineer in the country to design bigger and better aircraft for the airlines of today," said Captain Chainey, chief pilot.

The biggest problem confronting the pilot, opined Chainey, is lack of good visibility from the cockpit. Although seats are adjustable forward, aft, up, and down, it is still impossible to see all that should be seen with the nation's airways as crowded as they are today.

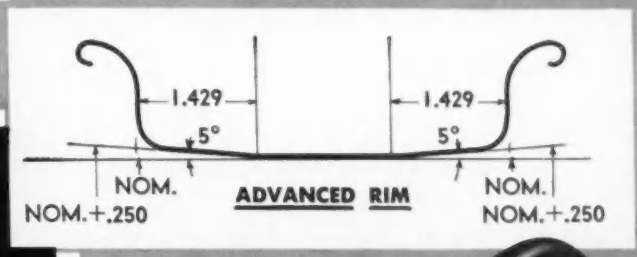
Flight Engineer Ganiey, next speaker, directed his talk toward air conditioning and heating units in the airplane. In order to have sufficient cooling of the airplane on the ground, a large turbine is needed, and at present the source of power to drive such a turbine is not available.

In the air, said Ganiey, heat distribution is uneven throughout the entire airplane. The cockpit may be "as warm as toast," but as you progress toward the rear of the plane, the air becomes considerably cooler. Ganiey said these are the major problems confronting air conditioning engineers at this time.

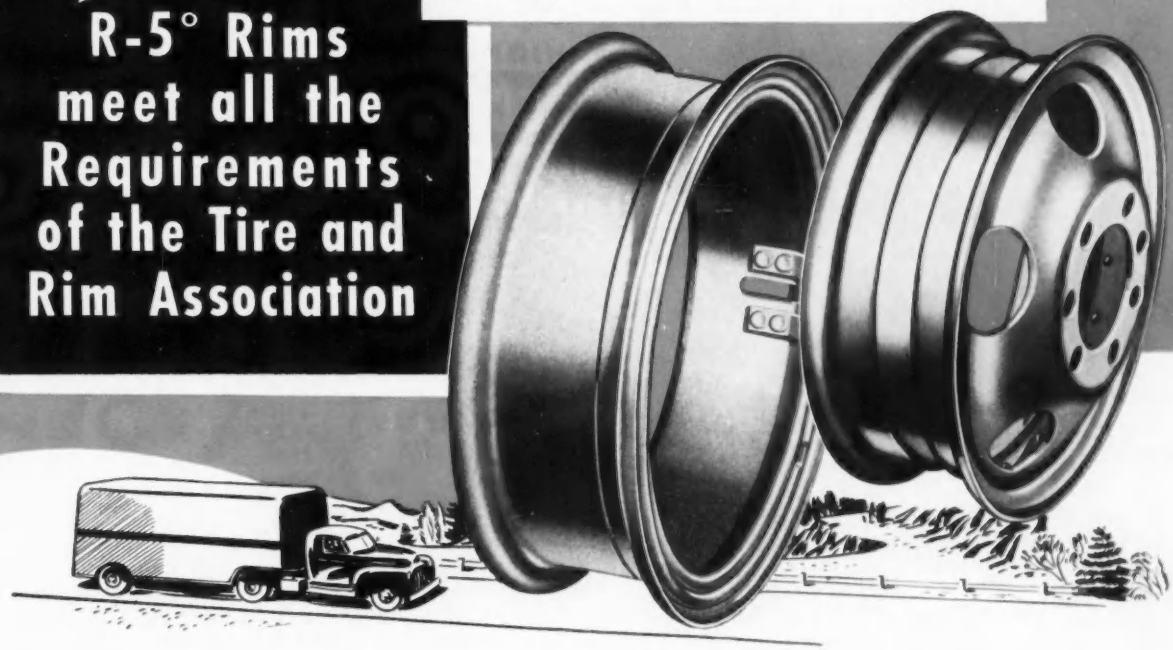
Flight stewardess Wendelton, whose

ST. LOUIS, MO.

Firestone Full Advanced Rims are the RECOMMENDED TRUCK-BUS RIMS



Firestone R-5° Rims meet all the Requirements of the Tire and Rim Association



THE diagrammatic sketch shown above is taken from the year book of the Tire and Rim Association. It gives the basic specifications of the Advanced Rim as worked out by tire engineers for improved tire mileage. And Firestone Advanced Rims meet these specifications "on the nose." There's no compromise of these basic requirements because of manufacturing or engineering problems; no substitute design; no interim or half-way rim. That's because Firestone completely retooled to give the truck industry the *only complete* line of Full Advanced Rims in all types and sizes.

Remember, only *Full Advanced Rims* are *"recommended for use in design of new vehicles,"* by the Tire and Rim Association. For complete information on why Firestone *Full Advanced Rims* will make your trucks a better buy write Firestone Steel Products Company, Akron, Ohio.

Listen to the Voice of Firestone every Monday evening over NBC

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Only Firestone Makes a Complete Line of Full Advanced Rims

duties are quite varied, said the largest is "to make the passengers feel at home. Probably the best means of insuring comfort to the passengers is to feel that they are guests in your home, not fare-paying passengers."

Coffee is served to anyone 24 hours a day. Books, pillows, and even bedroom slippers are furnished to insure passenger comfort. Although the job requires strict alertness at all times, Miss Wendelton says, "it's just a lot of fun."

New Members Qualified

These applicants qualified for admission to the Society between July 10, 1950 and August 10, 1950. Grades of membership are: (M) Member; (A) Associate; (J) Junior; (SM) Service Member; (FM) Foreign Member.

British Columbia Section

Gene L. Buckman (A), John W. Dobie (A), William L. Jones (M

Canadian Section

Stanley Brown (A), Wilfred James Chenery (A), William K. Ebel (M), Denis Pierpoint Edkins (M), Ewart A. Everson (A), A. John Grover (M), Reuben Allen Harvey (M), Roy Victor Jeffery (A), Paul L'Heureux (A), L. Wesley Maxwell (A), Gerard Plourde (A), S. A. Sadiq (M), Louis F. Vauthier (A).

Central Illinois Section

Robert A. Cumming (J), Yale M. Miller (J).

Chicago Section

Frank K. Burgess (J), J. T. Callaway (A), Howard Eberhardt (M), Hollis R. Hilstrom (M), Julius R. Koppelman (A), William P. Manos (J), Maurice T. Moler (A), John Edward Nelson (J), Joseph S. Tinaglia (A).

Cleveland Section

Clarence O. Bell (M), Ralph K. Boyer (M), Edwin A. Brezina (M), Pitt A. Curtiss (J), Walter J. Evans, Jr. (J), Andrew F. Haiduck (M), Frank J. Michelbrink (A).

Dayton Section

John F. Burridge (M), Marvin Davies Vance (M).

Detroit Section

Cleafe Allen Best (J), Robert H. Bollinger (M), Theodore E. Dougherty (M), Wesley S. Erwin (M), Milton A. Forester (M), Leslie S. Gaugh (A), Jahn R. Hollowell (J), R. Boyd Jones (J), Alexander J. Kosidlo (J), Wally Kozlowske (J), Robert C. Leary (M), Ralph R. Lord (M), Gordon McCririe (A), Foster H. Middleton (J), William Thomas Morden (J), Louis Muchy (M), Edward L. Nemetz (M), Harvey J. Nestle (A), R. C. Oglesby (M), John Joseph Olis (J), John A. Prokop (J), John Edward Quirk (M), James C. Rhodes (J), Arden J. Roberts (M), William A. Stearns (M), Kurt O. Tech (M), Homer S. Tolan, Jr. (J), Charles L. Waterhouse, Jr. (M).

Hawaii Section

John O. Spengler (A).

Indiana Section

William C. Edmundson (M), Herman Staggenburg (M).

Kansas City Section

Stuart L. Spradling (J).

Metropolitan Section

Peter Henry Cerf (M), Vincent D'Aversa (A), Robert William Eby (J), Paul A. Finn (A), William F. Geiler (M), William H. Holst (A), Richard Caldwell Kerr (M), Homer F. Malone (M), Thomas H. McConnell, Jr. (M), Eric Albert Meyer (J), Vincent J. Rossignol (A), James L. Ryan (J), Francis

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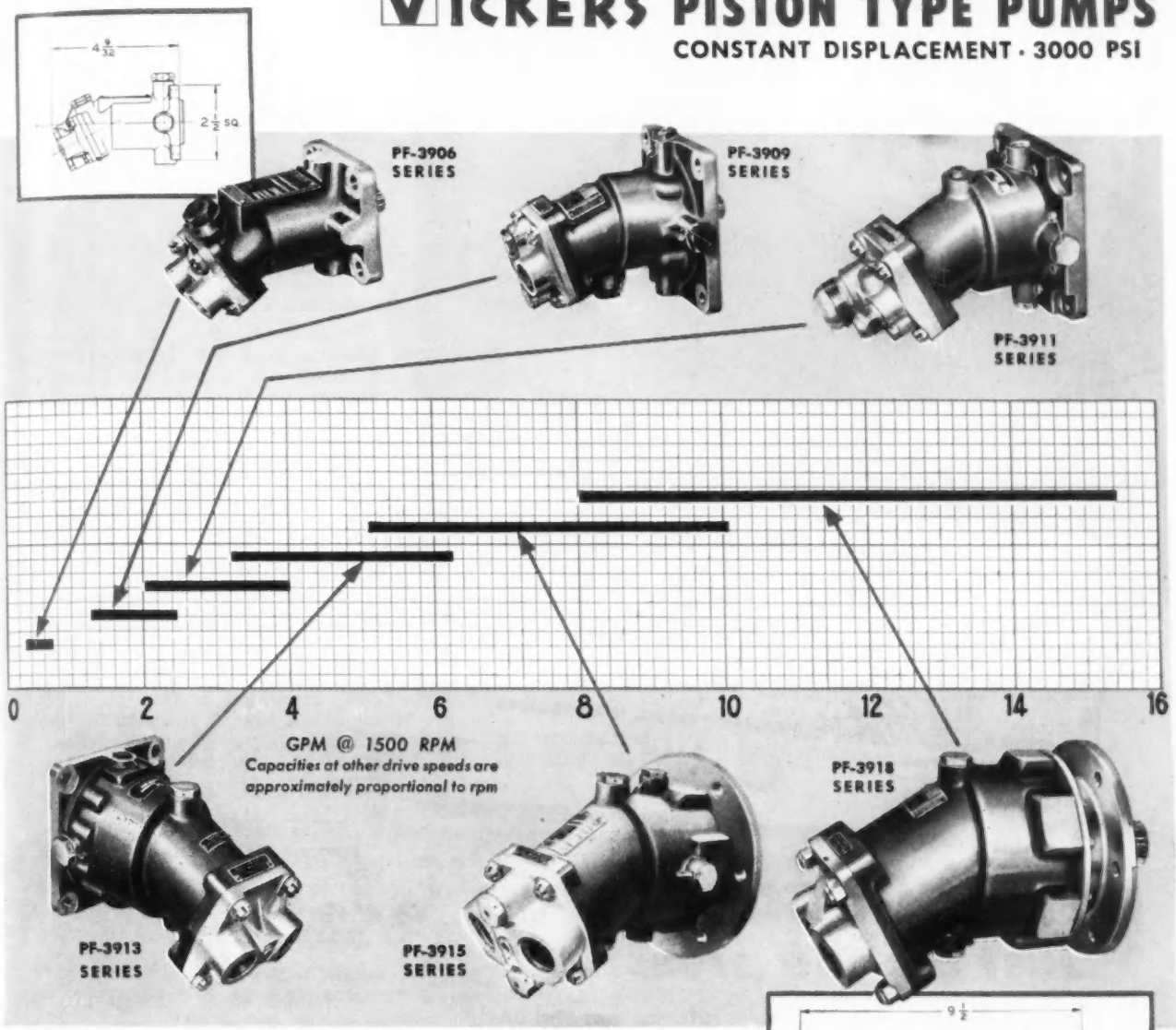

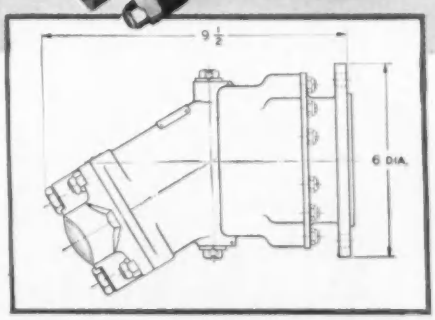

Each of the 6 basic model series of Vickers Constant Displacement Piston Type Pumps shown here is available in four capacities (angles) for continuous duty at pressures up to 3000 psi. The capacity range of each series is shown at 1500 rpm; at other speeds the capacities are approximately proportional. Capacity overlapping between series provides a flexibility of application that often simplifies installation, stocking and servicing.

All these pumps have earned a remarkable reputation for reliability. Airline life in excess of 10,000 hours has been reported. Volumetric and overall efficiency are very high. Small size and extremely high horsepower to weight ratio are notable characteristics. Write for Bulletin 49-53 describing Vickers . . . the most complete line of hydraulic equipment for aircraft.

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Northern California Section

Ernest William Boley, Jr. (A), William B. Royall (M).

Northwest Section

Rudolph Winslow Fredericks (A).

Oregon Section

Melvin L. Gordon (A).

Philadelphia Section

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San Diego Section

Fred W. Van Amburgh (M).

Southern California Section

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Southern New England Section

Edmond Louis Patton, Jr. (J), E. F. Zawacki (M).

Spokane Intermountain Section

P. L. Polizzotto (J).

Syracuse Section

Richard B. Clark (M), David I. Dilworth, Jr. (M).

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Virginia Section

William E. Bristow (A), Alfred Pemberton (M).

Washington Section

William Daniel Perreault (M), John Melford Sanders (A), Arthur Richards Smith (A).

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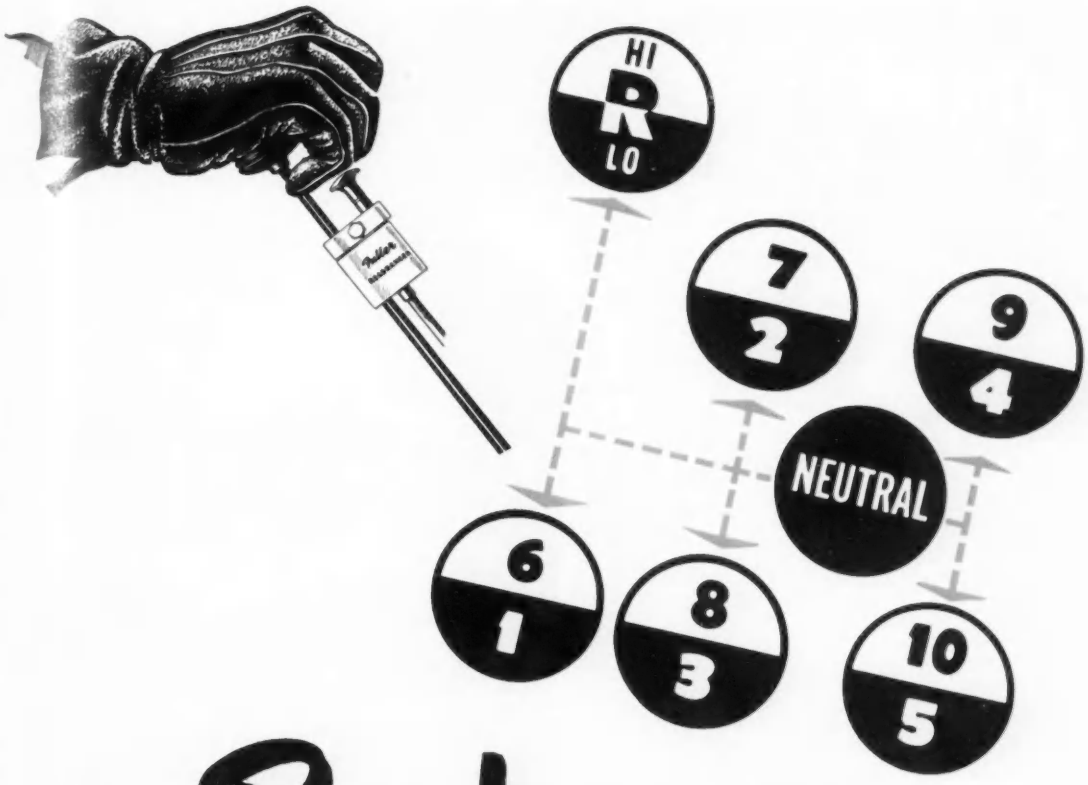
James Shelby Bowron (M), John Davis Calhoun, Jr. (M), George Rex Edwards (M), Capt. Luther Wesley Feagin (A), Harold V. Messick (M), F. E. O'Callaghan, Jr. (M), Robert J. Schroeder (J), A. Edward Smick (M),



the Roadranger

One lever controls *10* speeds without GEAR-SPLITTING

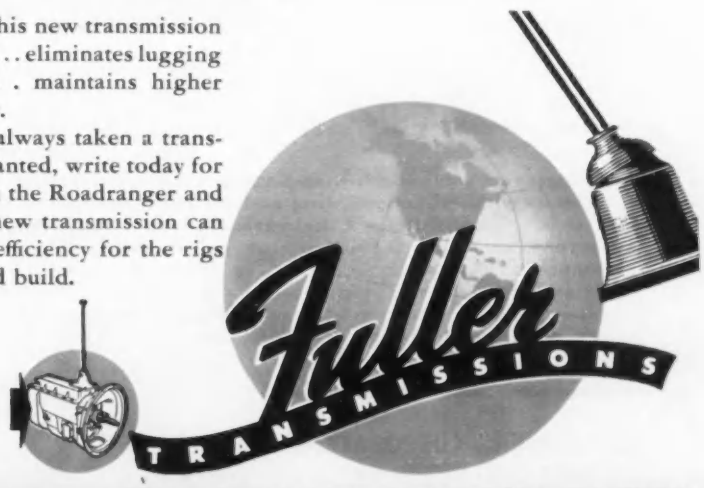
With the *new* Fuller Roadranger Transmission, you shift 1-2-3-4-5 . . .
Then, you push or pull the *range selector button,* shift through neutral and . . .
Go right back through the series for 6-7-8-9-10.
Yes, 10 speeds forward with *no gear-splitting.* Straight shifts all the way.

Think what this entirely new theory in transmissions can do for you, this two-range Roadranger where the 10 selective ratios are so evenly and progressively spaced that all shifts are only 28% steps!

First, ⅓ fewer shifts. Second, shifts are easier and quicker. Third, there is no waiting—the engine always operates at peak rpm.

That's why this new transmission helps save fuel . . . eliminates lugging after shifts . . . maintains higher average speeds.

If you have always taken a transmission for granted, write today for all the facts on the Roadranger and see how this new transmission can mean greater efficiency for the rigs you design and build.



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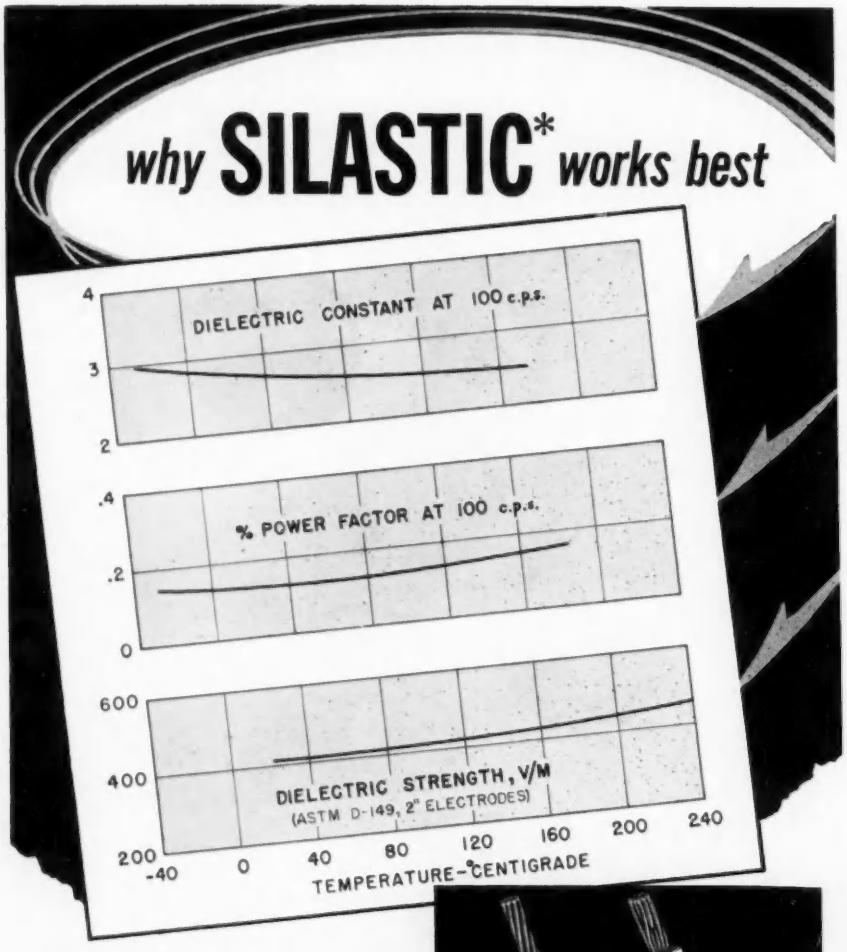
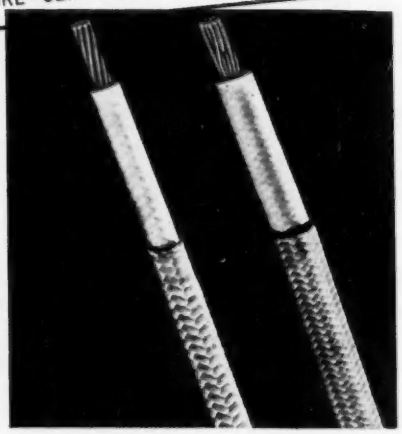


as a dielectric material from −100° to +500°F.

Over that wide temperature span only Silastic, the Dow Corning Silicone Rubber, remains resilient and retains high resistance to weathering, moisture, oxidation and ozone. Add good dielectric properties to those advantages and you have the reasons why Silastic is an excellent insulating material for high temperature, high voltage cable and for use in equipment where mechanical breakdown limits the effectiveness of resinous insulating materials.



Silastic is extruded over wire and cable ranging in size from No. 22 to 500,000 circular mils to provide insulation at temperatures from −80° to 400° F.*

Many engineers are familiar with Silastic as a remarkably heat stable and oil resistant rubberlike gasketing and sealing material for use between −100 to 500° F. Silastic as a dielectric for ignition and intercommunication cable and for field and armature coils is, however, a relatively new development. That's why Dow Corning has made available reprints of a recent article giving the most up-to-date information on the physical, chemical and dielectric properties of Silastic. To receive your copy, phone the nearest branch office or write for Reprint No. V-21.

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Applications Received

The applications for membership received between July 10, 1950 and August 10, 1950 are listed below.

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John H. Faunce.

Baltimore Section

Louis Arthur Herstein, III.

Buffalo Section

James E. Harter, Howard A. Mason, Daniel P. Murphy, James E. Shields, William B. Silvis.

Canadian Section

Edward Marshall Bauder, Albert Jervois Dewdney, Edward William Fryday, J. S. Smeaton.

Central Illinois Section

Edwin E. Hanson, William Leslie Matthew, Ernest Reginald Maxfield, Dwight W. Parken, Norman L. Woolgar.

Chicago Section

Joseph S. Cardillo, John J. Corrigan, Jr., Harry T. Hawthorn, Richard R. Jung, George J. Magee, Jr., John J. McKinnie, Philip C. Mosher, Philip R. Proctor, William R. Shimmin, Angus G. Sturrock, John N. Thilges.

Cincinnati Section

Norman G. Schacht.

Cleveland Section

Edward D. Alvord, Jr., Robert P. Buhrow, William L. Cratty, Kenneth D. Roberts.

Dayton Section

Dwight Richard Craig, Robert A. Minch.

Detroit Section

Jeremy T. Ball, Rudolph Michael Bogre, William Harold Chapman, John Festian, Francis C. Fleck, Stanley Gecewicz, James Robert Kelley, Robert E. Nelson, Anthony J. Pane, Gordon A. Price, Alexander R. Ross, Edgar T. Schreiner, William Scott, Gordon Reed Stone, Robert James Templin, Lawrence A. Warzel, Benjamin D. Thomas, Julius E. Witzky, Robert G. Yingling.

Turn to page 112

In these and more of the nation's great pleasure, commercial and "work-horse" vehicles the Aetna Clutch Release Bearing is standard equipment. No guarantee we might write could carry more significance than that fact, no greater proof of this bearing's ability to serve faithfully and faultlessly in your mobile vehicles too.

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- **Trouble-free Operation.** Nothing to get out of order . . . lasts the life of the car

Exclusive *'Electrimatic'* Features Assure Correct Choking at All Temperatures

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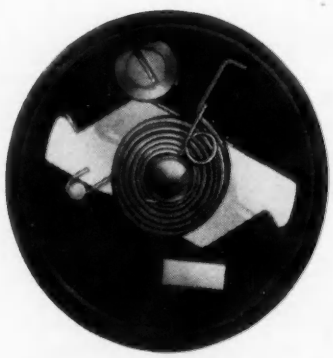

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Milwaukee Section

Jay L. Bruns, Kenneth G. Jones, Richard A. Mann, Arthur Junior Wolf.

Montreal Section

R. A. Armitage, Bernard Brunel, R. A. McLean, John Leslie Millen, George Robert Westwell.

New England Section

Michael Dobrolet, Christopher Guy MacDermot.

Northern California Section

Russell A. Anderson.

Northwest Section

Donald F. Branstrom, Garrett Duane Shaw.

Oregon Section

Remey M. Cox, Jr.

Philadelphia Section

Thomas Baldwin, Edward Peter Skralskis, Manfred Stein, Richard Edward Van Doren.

Pittsburgh Section

Adrain E. Dible, Bruce E. Markley.

St. Louis Section

Norman Roland Cooper, B. Morris Henderson.

San Diego Section

Reba W. Vemich (Mrs.)

Southern California Section

Richard L. Barter, Lowell E. Bloss, M. L. Cohn, Jack M. Craig, Kenneth C. Edson, John H. Kinsley, John Daniel Mark, Nick G. Stasinos.

Southern New England Section

Cornelius G. Houtsma.

Texas Section

Charles Richard Overly, Frederick Edward Wilson.

Twin City Section

Bernard E. Carlson, Wayne Eugene Simon.

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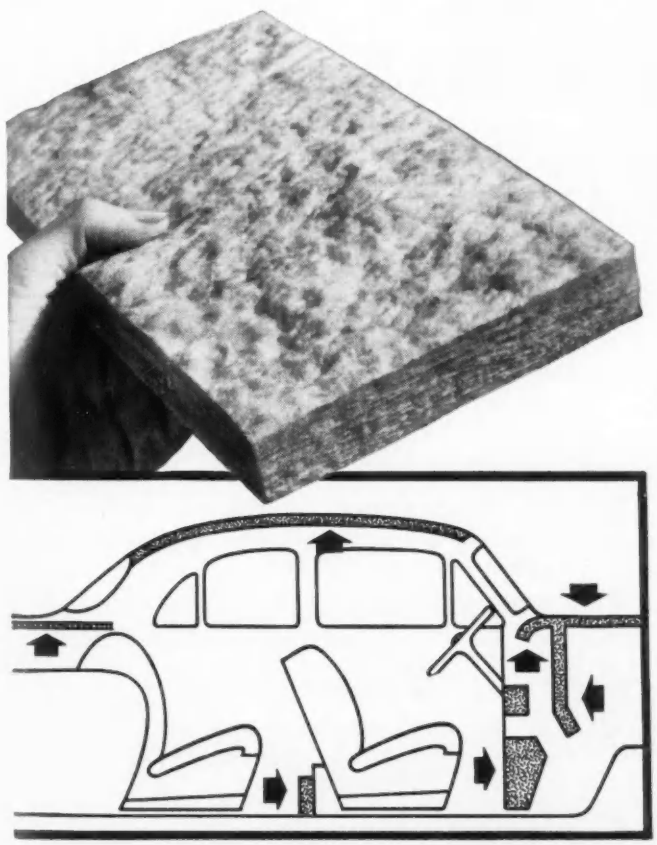

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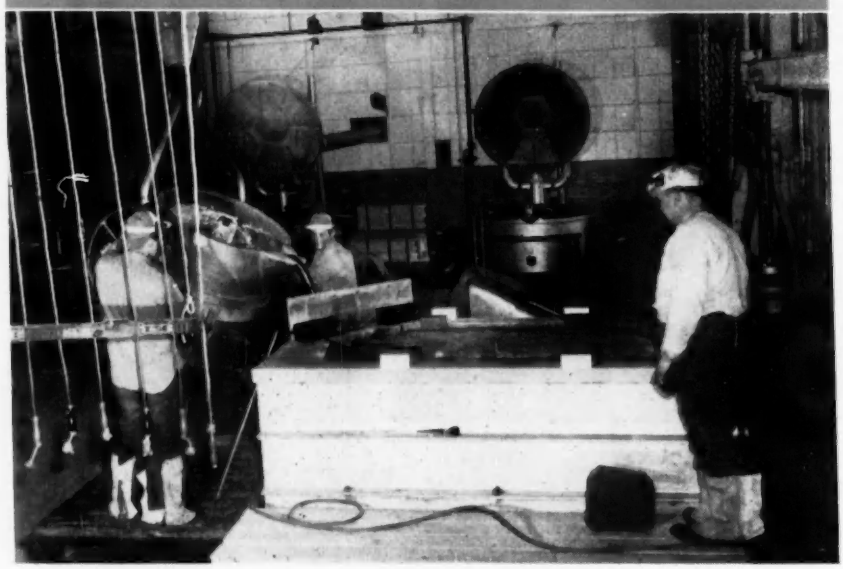

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Foreign

Miles Livingston Brubacher, Saudi Arabia; Badreddine Jundi, Syria; Mundkur Vasudev Kamath, India; Noel Ager Mackay, New Zealand; Charles Thomas Perera, Ceylon.

HAVE YOU Changed Your Address?

So that your SAE mail will reach you with the least possible delay, please keep SAE Headquarters and the Secretary of your local Section or Group advised of any changes in your address. Such notices should be sent to:

1. Society of Automotive Engineers, Inc., 29 West 39th St., New York 18, N. Y.
2. The Secretary or Assistant Secretary of your Section or Group at the addresses listed below:

Baltimore

R. L. Ashley, Ashley Chevrolet Sales, Inc., 2001 N. B'way, Baltimore 10, Md.

British Columbia

John B. Tompkins, British Columbia Section, SAE, 1010 Dominion Building, 207 W. Hastings St., Vancouver, B. C., Canada

Buffalo

C. J. Lane, 1807 Elmwood Ave., Buffalo 7, N. Y.

Canadian

F. G. King, Maclean-Hunter Publishing Co., Ltd., 481 University Ave., Toronto, 2, Ont., Can.

Central Illinois

M. M. Gilbert, 175 North St., Peoria, Illinois

Chicago

F. E. Ertsman, Chicago Section, SAE, 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill.

Cincinnati

L. W. Thorne, 615 Maple Ave., Cincinnati 29, Ohio

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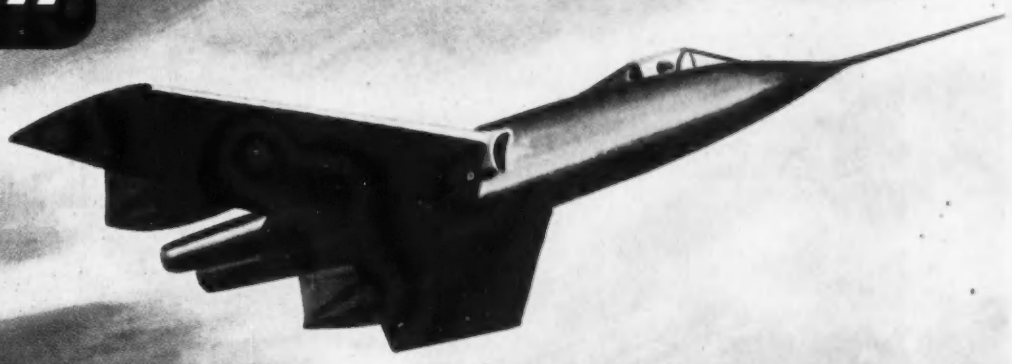

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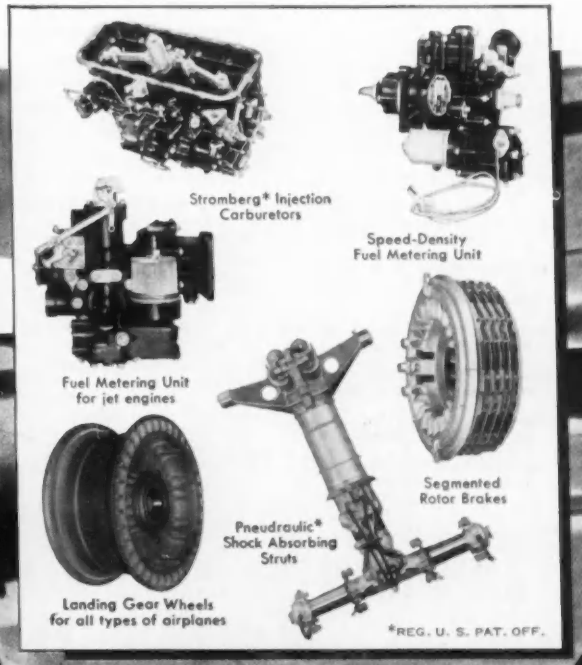
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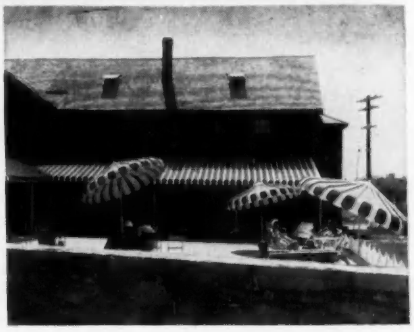

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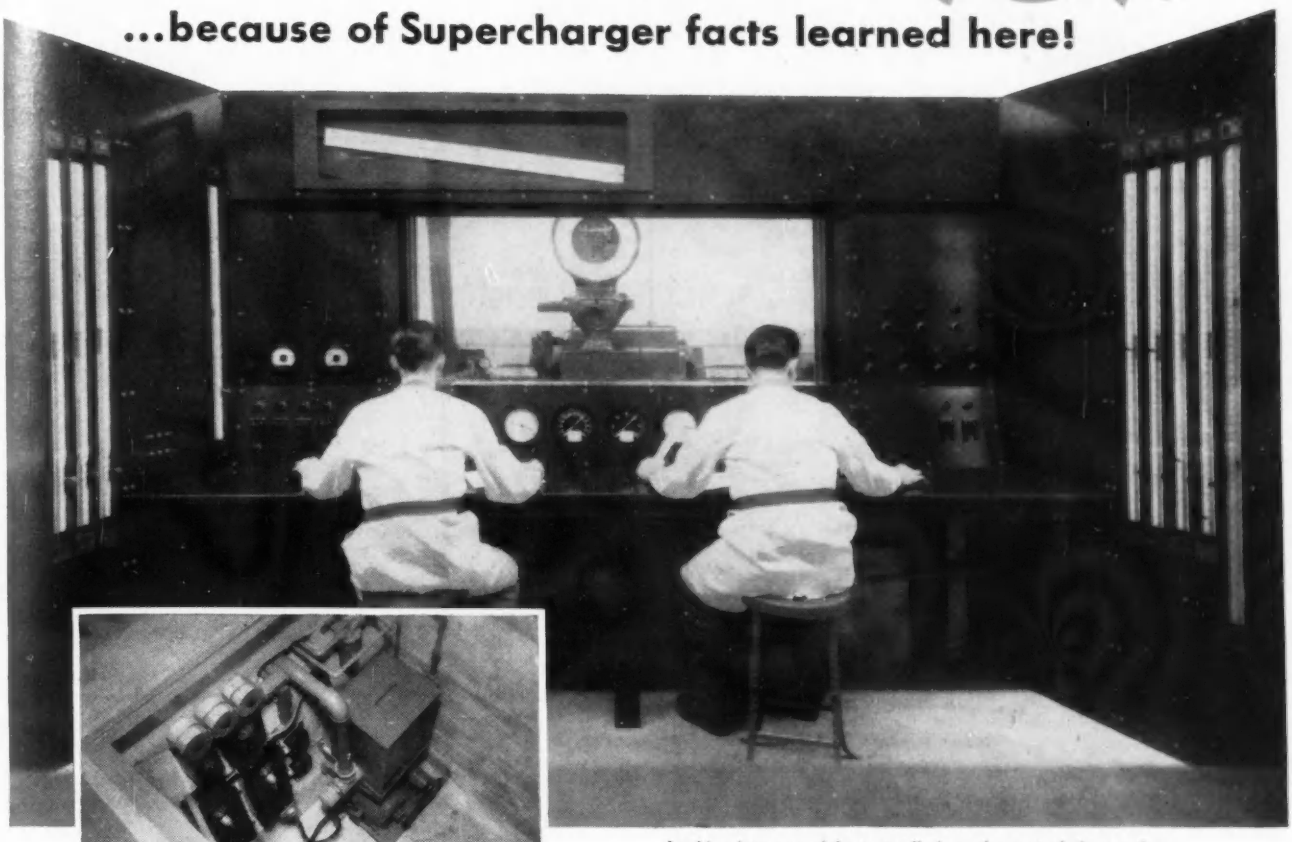
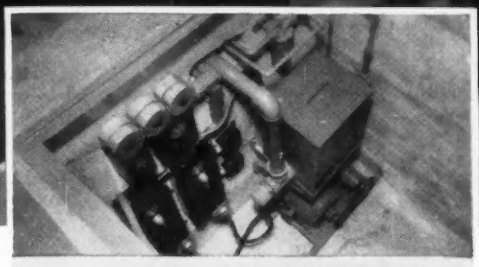
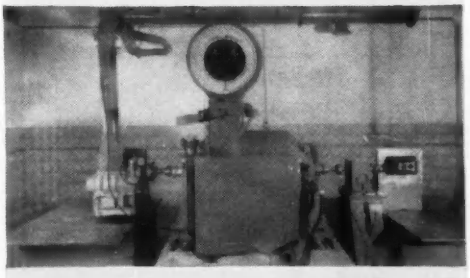


Looking into one of the test cells from the central observation room in which all conditions of the test are controlled.



The centrally-located and remotely-controlled oil system for Supercharger and equipment operation.



An observer's view of equipment and supercharger on test.

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